The Influence of Several Soil Management Practices in Florida on Nematode Populations

By
JOSEPH MARTIN GOOD, III

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA
August, 1955

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. G. D. Thornton for his helpful guidance in the study of this problem and for the planning of an academic curriculum that will be the basis for the solution of many future problems. The author is especially indebted to Dr. J. E. Christie for his guidance and instruction in the technical aspects of nematology and for the many kindnesses shown during our association. Appreciation is also expressed to Mrs. L. A. Hetrick, E. E. Jones, F. G. Smith, and E. G. Spinks for their constructive criticism of this work. Thanks are extended to Drs. W. K. Robertson and L. C. Thompson for the material aid they contributed to the study of crop rotations and to Mr. P. J. Westgate for his cooperation in the study of nematode-fertility relationships.

Appreciation is extended to Dr. F. B. Smith of the Soils Department and the University of Florida for providing a laboratory assistantship which made this work possible and for supplying the necessary instruments for conducting nematological research.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

APPENDIX TABLE

APPENDIX TABLE (Cont.) Page

INTRODUCTION

In the final analysis, field observations and experimentation are the ultimate answer to the selection of crops that will be resistant or tolerant to plant parasitic nematodes. Under the best conditions complete control or eradication of plant nematode parasites in our sandy soils probably cannot be achieved. If this is the case, tolerance levels for given crops that will give maximum yields for minimum cost must be ascertained. To achieve this end, more fundamental information is needed on nematode taxonomy, climatic relations, seasonal development, life cycles, microbiological inter-relationships, and soil and crop management practices.

Many questions of nematode population dynamics and ecology can be answered from in situ studies in which accurate species determinations are made for a given set of conditions, i e , crop rotation or soil fertility practices. Too often in the past, only one plant parasitic nematode species has been studied in relation to a given agricultural practice, neglecting other parasitic nematodes that may have entirely different host preferences. Recommendations from such observations are likely to result in the reproduction and multiplication of nematodes that were originally of minor importance to economic crop production.

This investigation was initiated to answer some of these questions. Nematode populations at various seasons of the year were studied to determine the influence of crop rotations on plant parasitic, predaceous, and saprophytic nematodes. Inasmuch as high fertility by providing more healthy and vigorous plants for the nematode to feed on may affect

nematode populations, studies were undertaken to evaluate the influence of soil fertility on these organisms. Comparative studies on the reproductive rate of sting nematodes on a number of cover crops were evaluated to obtain more information on the hosts of this important ectoparasite. Necessarily, the established methods of extracting nematodes from the soil had to be evaluated for the conditions of this experiment and for Florida conditions

LITERATURE REVIEW

The review of previous work on plant parasitic nematodes will be limited to those species that are actually involved in these investigations and to researches on crop rotation and nematode-nutrient relationships.

The Sting Nematode

The sting nematode Belonolaimus gracilis Steiner, 1949 was first observed associated with the roots of corn at Sanford, Florida, and with seedling roots of slash and long leaf pine from nurseries at Ocala, Brooksville, and Valparaiso, Florida (32). Since that time, the devastating behavior of this parasite on a number of crops has been established. Christie, Brooks, and Perry (12) found the sting nematode to be a major parasite in Florida on strawberries, celery, and sweet corn. On corn and celery, injury to the growing root tips will often cause short, stubby branches to develop, resulting in a root system that is restricted to the upper three to four inches of the soil. Infested areas may be isolated spots of stunted plants, or these spots may coalesce so that the entire field may be involved. The list of susceptible crops was further expanded by Christie (11) to include beans, soybeans, cowpeas, peanuts, millet, cotton, peppers, squash, sorghum, and onions. Working in South Carolina, Graham and Holdeman (42) found this parasite caused severe damage to cotton, corn, soybeans, and cowpeas. In inoculation studies conducted by Graham (41), tobacco plants were not injured by the sting nematode. Owens (69) found that the sting nematode was capable of causing severe injury to peanuts in Virginia. Injured plants showed rubbed-off roots, often

to such an extent that only the major roots remained. Good, Christie, and Hutter (34) found the sting nematode to be one of the most important nematode parasites of a large number of grasses throughout most of the State of Florida. Its pathogenicity on clover was demonstrated experimentally by Good and Rhue (35). In a summary of the known distribution of the sting nematode, Holdeman (45) reported that the sting nematode was a parasite of widespread importance in the Southeastern United States, having been reported from Virginia, North Carolina, South Carolina, Georgia, Florida, and Louisiana. It was reported in 34 counties in Florida.

Meadow Nematodes

In 1865 Bastin (5) proposed the genus Tylenchus. This genus eventually contained many different species, including Tylenchus pratensis, which was described by de Man (50) as a free-living soil nematode. Baylis and Daubney (6) transferred most of these species to the genus Anguillulina Gervais and van Beneden, 1859. When Filipjev (29) subdivided the old genus Tylenchus, he erected the genus Pratylenchus, making Pratylenchus pratensis the type species. The number of valid species, probably 15 or 16, remains questionable; though at the present time the taxonomy of this group through many redescriptions, new combinations, and synonymies has become more intelligible (10, 78). The most important meadow nematode species of field crops in the Southeastern United States are P. leiocephalus, Steiner, 1943, and P. zeae Graham, 1951, (40).

The term meadow nematode originally referred to Tylenchus pratensis.

the word "pratensis" means pertaining to or growing in a meadow. Through usage, meadow nematode now refers to the genus Pratylenchus. The common name of lesion nematode is preferred by some workers because it indicates the nature of injury to plant roots. Either meadow nematode or lesion nematode are acceptable common names (7).

Meadow nematodes are small, elongated tylenchoid nematodes, ranging from 0.3 to 0.9 mm. in length. These nematodes are migrants in that all stages may be found in the roots and soil (44). Working with cane root cultures of P. penetrans, Graham (40) showed that at 75° - 80°F eggs hatched in 15 to 20 days, larval molts required an additional 15 to 20 days, and the completed life cycle required 35 to 40 days. The developmental period of different species varied (31, 43, 61, 85). Optimum reproduction of P. leiocephalus and P. penetrans occurred at a soil temperature of 80° - 90°F with a peak in the population density in mid to late summer and a depression during the winter (40). In addition, Graham (40) found that meadow nematodes were carried over winter in the soil and plant roots. More nematodes were found in the soil than in the roots in the winter. During the winter, the population existed in decreasing order in the roots of the following plants: crabgrass, cotton, corn, and tobacco. These organisms are capable of entering the root at any point, even in woody portions (40, 83). In the case of corn, early symptoms of infestation are small water-soaked areas, which gradually enlarge, turning brown or reddish as time progresses. These lesions gradually enlarge until the root is girdled, resulting in the death of the distal portions (40, 61, 83).

In discussing the economic importance of meadow nematodes

Steiner (83) stated that they are "doubtless one of the most important primary factors in root destruction among cultivated and uncultivated plants. The overall damage caused by these pests in the United States is possibly greater than that which is attributed to the root-knot nematode". Well over 100 different host plants have been reported throughout the world. Included are field crops such as alfalfa, barley, corn, cotton, oats, rye, tobacco, wheat, and millet; vegetable crops such as tomato, strawberry, yam, mustard, beet, cabbage, carrot, lettuce, okra, potato, spinach, eggplant, and peppers, leguminous plants such as clovers, cowpeas, lupines, peas, soybeans, vetch, and peanuts (8, 20, 22, 25, 33, 39, 44, 47, 62, 64, 81). Complete losses of soybeans in Brazil due to meadow nematodes have been reported (53) Extensive and severe damage to alfalfa are known to have occurred in Kentucky over the past two decades. Chapman (8) associated these failures with meadow nematode infestations. In studies conducted by Graham (40), losses of tobacco in South Carolina, North Caroline, and Georgia due to meadow nematodes ranged as high as 43 percent, which would amount to several million dollars annually in each of these states.

The Awl Nematode

The awl nematode Dolichodorus heterocephalus Cobb, 1914, originally was thought to be a fresh-water species. Cobb (19) described this species from Douglas Lake, Michigan, and Silver Springs, Florida. It is now clear that this nematode is capable of inflicting severe damage to many agricultural crops and grasses throughout most of peninsular Florida where it has been reported from soils with high water tables or from soil that is maintained at a rather high moisture level by irrigation.

Steiner (82) found this nematode associated with the roots of celery in the Sanford, Florida, area. The pathogenicity of the soil nematode was conclusively verified by Perry (71) and Barjeu, Lownsbery, and Hurley (86). In experimental tests this nematode caused chlorosis, stunting, and production of stubby secondary roots on corn, tomato, celery, pepper, and soybeans.

Stubby-Root Nematodes

A stubby-root nematode was first described by de Man (58) in 1880 as Dorylaimus primitivus, but changed in 1922 to Trichodorus primitivus by Micoletzky (60). A second species was described by Cobb (18) in 1913 as Trichodorus obtusus. Christie and Perry (14) were the first to establish this species as a plant parasite of beet, sweet corn, bean, cabbage, cauliflower, celery, cowpea, lima bean, pea, pepper, soybeans, and tomato in Florida. The species involved did not appear to be one of the described species; therefore the organisms were referred to as Trichodorus spp. They reported that stubby-root nematodes are widespread in the South and are apparently external, root feeding nematodes, causing the "stubby-root" condition. This condition results from these nematodes feeding at the root tips, which apparently devitalizes the root. As more lateral roots are put out by the plant, these in turn are devitalized, resulting in a coarse, restricted root system that is not capable of supporting healthy, vigorous above ground plant parts. In South Carolina, Graham (41) found corn, cowpea, cotton, and various grasses injured by Trichodorus sp. The number of grasses attacked by this pest has been expanded by Good, Christie, and Hutter (13, 34) to include Bermuda, St. Augustine, Centipede,

Zoysia, and Pensacola Bahia.

Ring Nematodes

Ring nematodes, Criconemoides Taylor, 1936, are short, stout, and heavily annulated. They are ectoparasites which become partially embedded in the root tissue where they feed with their well developed stylets. Some necrosis is produced around the area in which this organism feeds (82). Criconemoides citri Steiner, 1943, has been described as a parasite of sour orange in the region of Orlando, Florida (82). Many other species have been described by Taylor (87) and Raski (72). Chitwood (9) found as many as 10,000 specimens of C. similis (Cobb, 1918) Chitwood, 1949, in 200 grams of soil from around peach tree roots. Associated with these high populations was a decline of peach orchards in North Carolina and Maryland. Little is known about the effects of ring nematodes on field crops; however, Machmer (56) found that peanut "yellows" was associated with ring nematodes in Georgia. Chlorotic areas in one peanut field contained 546 ring nematodes per 600 cc. of soil while adjacent green areas contained only 15.8 ring nematodes per 600 cc of soil. In a survey of the peanut growing areas of Georgia, Machmer (57) reported that ring nematodes occurred frequently around peanut roots and often comprised 60 percent of the total plant parasitic nematode population.

Dagger Nematodes

The genus Xiphinema and the type species X. americanum were described by Cobb (18) in 1913. He found X. americanum to be common on both the Atlantic and Pacific slopes of the United States where it was associated with the roots of corn, grass, and citrus trees. A number of additional

species have been described (36, 52, 54, 90); but, thus far, these have not been reported from the Southeastern United States. According to Christie (11) the American dagger nematode, X. americanum, appears to be widespread on oaks, shrubs, azaleas, and pecan trees in Florida. The roots of affected plants showed extensive surface necrosis and were largely devoid of secondary roots except for isolated bunches of short, stubby-roots. Schindler (76) found that small galls on roots of roses grown in the Northeastern United States were caused by the dagger nematode, X. diversicaudatum (Micoletzky, 1927) Thorne, 1939. In addition to the small galls, which caused curling of the root tips, there was necrosis and shriveling of the proximal ends of the roots. These same symptoms were produced on inoculated tomato, soybean, okra, cucumber, balsam, and peanut plants.

Lance Nematodes

The lance nematode type species, Hoplolaimus tylenchiformis, was originally described from a single specimen from Paraguay by Daday (25) in 1905. The description of the genus was amended by Cobb (23) in 1923 at which time he described a new species, Hoplolaimus coronatus. In 1949, Thorne (89) described another lance nematode, H. uniformis, which is of importance in Europe.

Lance nematodes are large, robust, cylindrical parasites with a stout piercing stylet. According to Steiner (82) their feeding habits resemble those of the meadow nematode in that they are often found in the cortex of the plant roots. Lance nematodes must be considered as both endo- and ectoparasites because they have also been observed feeding at

the surface of the plant roots. Steiner (79, 82) has observed H. curvatus in the roots of slash and long leaf pine seedlings, cane, red clover, sugar cane, and alfalfa. In the Netherlands, Oostenbrink (65) found H. uniformis associated with "sickness" of carrots, scorzonera, lettuce, asparagus, and peas. Christie, Good, and Rutter (13) reported that H. curvatus was very common in Florida and occurred as a major parasite of many grasses. They observed that this parasite was capable of entering the roots and producing necrosis and sloughing of the outer layers which results in death of the distal portions of the root.

Soil Fertility and Nutrient Relationships

A great deal of attention has been and is being paid to above ground symptoms of plant disease with only a superficial regard for the association of plant roots with disease complexes. Nematologists, particularly those who have worked in Florida, are of the opinion that many of our deficiency symptoms would be minimized if plant roots were not restricted and injured by plant parasitic nematodes. In cases where nematode injury seriously threatens crop production, interest in plant parasitic nematodes becomes keen. Chronic nematode infestations of low intensity are often overlooked, being mistaken for nutritional problems which would be nonexistent if plant roots were not injured by nematodes, especially the ectoparasitic ones. Published information on this type of infestation is meager. In southern Georgia, Machmer (57) found that fumigation for nematode control in flatwoods soils was superior to fertilization as a means of prolonging the productive period of Louisiana white clover. In Florida, many grasses have failed to respond to fertilizer

and increased moisture. On many occasions, this condition has been associated with high populations of plant parasitic nematodes (34). According to Kinnaird (48), in the North Florida area heavy applications of fertilizer allow profitable tobacco crops to be grown in spite of heavy infestations of root-knot. On the other hand, a root system that is free from nematode injury can more efficiently absorb soil materials than a restricted, injured root system, thus reducing the need of heavy fertilizer applications (82).

Concerning potassium, Tyler (93) reported that this element was helpful in protecting plants from root-knot nematode injury. Applications of potassium fertilizers may be of value in reducing crop losses on potassium deficient soils. However, fertilizing to overcome crop failure due to nematodes usually only prolongs the effect of the parasites. In addition, it probably builds up the nematode population through the influence of more succulent root production, which serves as a richer food source for the parasites. Such a condition is suggested from the observations of Farris and Noble (70) where they found root-knot infested lima beans deficient in potassium despite an adequate supply in the soil for normal crop growth. As early as 1903 Hilgerth and Wimmer (95) found that potassium, nitrogen, calcium, sodium, and magnesium levels were lower in nematode infested sugar beets than in non-infested plants. In chemical analyses of boxwood tissues, Terjan (85) found that roots containing meadow nematodes had more nitrogen and sodium, and less potassium than healthy controls. Leaves from nematode infested plants contained a higher level of phosphorus and a lower level of potassium than control plants.

In a series of physiological studies, Otsifa (66, 67, 68) found that root-knot, Meloidogyne incognita, infected lima beans were lower in total nitrogen, phosphorus, calcium, magnesium, and potassium than the controls. As might be expected, Otsifa found that with a constant root-knot inoculation rate additions of potassium increased plant growth. Also, potassium adsorption by the plant was reduced by increasing the infestation; however, additions of potassium helped to compensate for root-knot injury. Plant tissue levels of potassium were important in determining the reproductive rate of root-knot nematodes. With increasing potassium levels, egg production was considerably accelerated.

Crop Rotations

The use of crop rotations is a practical method of preventing parasitic nematode populations from building up in soils. However, crop rotations are more valuable in preventing the build up of nematode populations than in reducing heavy infestations once they are established (32). To date, most crop rotations for nematode control have been devised for the control of root-knot organisms with little regard for other plant parasitic nematodes. It would be desirable to design rotations that would control all nematodes likely to be found in a given area; however, the presence of two or more species reduces the number of crops that can be used in the rotation (75).

To prevent an initially low population of one species from building up while trying to control another, it is important to change the rotation. Steiner (80) suggested that such a practice will prevent species adaptability to specific hosts. For this reason, crop rotations

prevent nematodes from adapting to a single crop. Steiner is of the opinion that nematodes will develop stronger host preferences the longer a susceptible crop is grown. When the crop is changed several years may elapse before the nematodes will produce any appreciable injury; even though they were originally present in large numbers. This, in theory, may be sound but cannot be universally true, for Graham (40), Garriss (32), and Mountain (61) have found that tobacco following corn was severely injured by meadow nematodes. Apparently it is true that tobacco is not a preferred host because meadow nematode populations are not as large in continuous tobacco plots as they are in continuous corn plots (40, 74). Steiner (80) also suggested that if susceptible crops have to be grown, other crops in the rotation should be botanically separated. Different families should be selected when possible.

For control of root-knot on tobacco, Garriss (32) suggested the use of long rotations, three- and four-year rotations being preferred to two-year rotations and continuous tobacco. According to Garriss the best four-year rotation would be cotton, corn, peanuts, and tobacco. Even with this rotation, yields will gradually decrease unless the rotation is changed, that is, substitute crotalaria, cote-weeds, weeds or sod top for one of the cash crops in the four-year tobacco rotation. Crop rotation studies from southern Georgia over the past twenty years indicated that more root-knot developed on tobacco planted after nematode susceptible cowpeas, sweetpotatoes, and corn than after other principal crops grown in this area (2). Less root-knot on tobacco developed following Spanish peanuts, cotton, velvet beans, and weeds. Later information from the

Georgia Coastal Plain Experiment Station (3) suggested that three-year rotational systems are practical and reasonably safe, though not as effective in reducing root-knot as the four-year rotations. In addition to the above crops, Dixie Runner peanuts, millet, Sudan grass, and beggarweed may safely be used in rotations. Lespedeza, Austrian winter peas, and vetch are not advised because they increase root-knot and result in low tobacco leaf grade, and when cowpeas or soybeans are grown, a four-year rotation will be necessary. In a study of a number of two-year rotations and continuous cropping practices, Bonsar (74) found that peanuts following tobacco reduced root-knot to a trace, and in contrast to the findings of other workers, tobacco following cotton reduced root-knot populations. Onte-weeds following tobacco were more effective in reducing root-knot infestation than were weeds alone. Clayton, et al. (17) found that crotalaria and Dixie Runner peanuts give the best results when used in rotation with tobacco. From extensive studies of crop rotations for control of root-knot at the North Florida Agricultural Experiment Station, clean fallow, when incorporated into crop rotations, gave good control of root-knot (30). The control effect of clean fallow was attributed to (a) aeration which promotes hatching of nematode eggs; (b) starvation of larvae in the absence of host plants; (c) the direct effect of heat; and (d) dehydration of larvae from the drying of the soil surface.

Spanish and Dixie Runner peanuts have been reported as being resistant to root-knot, thus, reducing the incidence of this organism on crops that follow. Peanuts have been reported to be susceptible to

root-knot (56). Sasser (75) found that Spanish peanuts were resistant to all species of root-knot nematodes except M. hapla and M. arenaria. Peanuts will be of value in reducing root-knot only when these two infective species are not present in the soil. Fortunately, these species have not become widespread in the southern peanut growing areas of the United States, however, M arenaria has caused almost total losses of peanut crops in certain areas of the lower Chattahoochee River Basin in southern Georgia (55) M hapla on occasions has been found on peanuts in southeastern Alabama (96). According to Christie (11), M. hapla has been found on several occasions in Florida

The use of cover crops is an important adjunct to any crop rotation system. Sound judgment must be used in their selection if supplemental control of plant parasitic nematodes is to be achieved through their use. The number of cover crops known to be resistant or only slightly susceptible to root-knot is small. Crotalaria spectabilis, Crotalaria mucronata, and common ragweed are resistant to M incognita var acrita, M hapla, M. javanica, and M. arenaria (75). Both Kincaid (49) and Watson (94) found velvet beans to be resistant to root-knot in Florida, and they have proved practical in rotations for the control of root-knot. Oats, though slightly susceptible to M incognita, M javonica, and M arenaria (75), may be used in conjunction with Crotalaria striata and Crotalaria spectabilis in controlling root-knot (16). The use of C. spectabilis as a summer cover crop and oats as a winter cover crop under peach trees reduced root-knot infestation and increased tree growth and fruit yields in North Carolina and Georgia (16, 59). Vetch is rather

susceptible to root-knot, but it serves a useful purpose in crop rotations where it can be grown as a winter cover crop or catch-crop that is turned under before root-knot nematode females reach maturity and lay their eggs (92), thus reducing the infective potential for succeeding crops.

Crop rotations for the control of meadow nematodes have been only superficially investigated. Most of the studies have been made in relation to tobacco production. Tobacco grown after either cotton or corn suffered more from root-rot than when grown after weeds or peanuts, or when tobacco was grown continuously (40). Sasser (74) found that corn and cotton built up meadow nematode populations about twice as rapidly as tobacco, peanuts, cotton-weeds, and weeds. In Canada, Mountain (61, 62) found injury to tobacco associated with P. minyus when tobacco followed corn, rye, red clover, oats, or soybeans. From the Netherlands, Oostenbrink (65) observed that high populations of Pratylenchus occurred following barley, rye, oats, and wheat. In addition to these crops, Goffart (33) reported that in Germany meadow nematodes injured red clover, peas, lupine, and alfalfa.

Control of meadow nematodes may be possible by crop rotation, but Mountain and Boch (62) believe that crop rotation will be of little benefit when two or more species of meadow nematodes with different host preferences infest the soil.

Thus far, crop rotation for the control of endoparasitic nematodes of the root-knot and meadow nematode types have been discussed. There remains another large group of parasitic nematodes, the ectoparasites, but a review of the literature indicates that little is known about the

relative susceptibility of hosts to this important group. As pioneers in this field, Halderman and Graham (46), using pot culture techniques, have produced significant differences with respect to sting nematode populations on a number of crops. All grasses tested built up the population while ragweed and cocklebur maintained the original population. Jerusalem Oak, lespedeza, crotalaria, and peanuts reduced the population. Sting nematodes disappeared from pots containing crotalaria alone, but were able to maintain a sizable population in pots where crabgrass and crotalaria were grown together.

Methods of Removing Nematodes from the Soil

The method used for isolating nematodes from soil and plant tissue varies, depending on a number of conditions, such as purpose of examination, nature of the soil, type of plant tissue, species of nematodes being isolated, and individual preferences of the investigator. There exist several recent publications that outline these various techniques for separating nematodes from soil and plant tissue (27, 30, 38, 51, 76, 84, 88 and 97).

In removing nematodes from the soil, most investigators use either a modification of Cobb's sifting and gravity method (21) or a modification of Baermann's technique (4). Christie and Perry (15) greatly facilitated the extraction of nematodes from soil by combining the basic principles of these two methods.

The original Baermann funnel was used for the separation of hookworm larvae from soil (4). Baermann's apparatus consisted of a large glass funnel with an attached section of rubber tubing which was closed

at the tip by a clamp. A metal sieve of 1 mm. mesh was covered by a piece of fine cloth fabric and placed in the glass funnel containing sufficient water to cover the bottom of the sieve. Soil containing hookworm larvae was then placed on top of the cloth. After the nematodes had been given sufficient time to migrate through the cloth and sieve, they were drawn from the bottom of the funnel by opening the retaining clamp. Baermann conducted 13 experiments with this funnel to determine the best conditions for recovery of hookworm larvae. He concluded that migration of larvae started immediately after submersion, and after 24 hours all larvae had migrated through the sieve. The efficiency of the method was such that out of eight larvae placed in sterile soil, seven were recovered.

Using Baermann's technique, Cort, Ackert, Augustine, and Payne (24) considerably increased our knowledge of the usefulness and limitations of the Baermann funnel. From their studies on isolation of hookworm larvae, they concluded that (a) more larvae can be isolated from coarse soils than fine textured soils like clay, (b) the water in the funnel must be 10°F above that of the soil, (c) most larvae migrate through the sieve during the first six hours, but many more are extracted within 24 hours, and (d) the percentage of nematodes recovered is increased by reducing the size of the soil sample.

Recently, Anderson and Yanagihara (1) have modified the Baermann technique, and found that nematode extraction efficiency was increased several times. They substituted 12 ounce conical paper cups for the glass funnel, cleansing tissue for the cloth fabric, and 16 mesh window screen for the 1 mm. mesh sieve.

Cobb's method (21) consists of two parts: gravitational settling of heavy soil particles and use of sieves to remove large organic particles and colloidal particles. The soil sample to be examined is placed in a vessel with 10 to 20 times as much water as soil. The sample is thoroughly roiled, and after standing five seconds the sand and gravel settle out. the nematodes are suspended in the supernatant fluid, which is then decanted into another vessel. This washing process is repeated several times until all nematodes have been removed. The fluid containing the nematodes is poured over a series of superimposed sieves ranging in size from 16 to 200 mesh, or finer. Silk bolting cloth makes an excellent sieve. When a stream of water is passed over the nest of sieves, larger organic material is retained on the coarse sieves, nematodes are retained on the fine sieves, and colloidal particles are washed through. The nematodes and the remaining fine organic material can then be washed into a suitable container for concentrating the nematodes for subsequent microscopical examination.

In nematological examinations, it is desirable to study soil nematodes in clear water that is free from debris. Neither the Baermann method nor the Cobb method achieves this goal; however, a combination of the basic features of the two methods allows collection of soil nematodes in clear water. In the washing operation, Christie and Perry (13) suggested using approximately one pint of soil to four parts of water in a container suitable for roiling and decanting. After thoroughly roiling, the heavy particles will settle out in a few seconds, and the nematodes and particles of low specific gravity can be decanted onto the

sieve next. Three such washings will generally remove most of the nematodes. In the sieving operation, two sieves are used. the top sieve, which may be of 20 to 24 mesh, retains coarse organic material while the bottom sieve, 150 to 200 mesh, retains most nematodes and whatever fine sand and organic matter that has and been removed up to this point. Repeated washing of the sieves with tap water under pressure washes out colloidal particles. The contents of the fine sieve are washed into a modified Baermann funnel. This consists of a glass funnel, six inches in diameter, equipped with a bowl-shaped muslin sack that is supported by a wire hoop. The spout of the funnel is closed by a section of rubber tubing and pinch-clamp. Before the contents of the sieve are washed into the funnel, it should be filled with tepid water (90°F) to a level above the bottom of the sack. Within 24 hours, a large percentage of the nematodes can be drawn from the funnel by opening the pinch-clamp and allowing a few cubiccentimeters of water to run into a Syracuse watch glass.

In using the Christie-Perry modification of the Baermann funnel, Feder and Feldmesser (28) found that all nematodes did not collect at the bottom of the funnel spout. By applying suction on a Buchner funnel containing a fritted glass wafer, the entire water contents can be drawn through the funnel. the nematodes are collected on the surface of the fritted glass wafer. Using a wash bottle, the nematodes can then be washed into an emulsion dish with as little water as 5 cc. The use of this concentrating device and the Christie-Perry method allows efficient extraction of nematodes from soil samples.

PROCEDURE

Field plots for the study of the effects of crop rotations and soil fertility on soil nematode populations were located at the North Florida Agricultural Experiment Station, Quincy, and the Central Florida Agricultural Experiment Station, Sanford, respectively. These plots were planted,maintained, and harvested by station personnel.

Field soil samples for the nematode studies were taken from the two harvest rows of all plots. In the field the harvest rows between plots were separated by at least two guard rows. This minimized the error likely to occur from the placement of plots from season to season, the mixing of the soil between plots during cultivation, and the action of rain drop splash and running water. For the same reasons, a border of three feet was not sampled at the end of plot rows. The samples were taken from the root zone to a depth of six inches with a standard one-inch soil sampling tube. Approximately one quart of soil was taken from each plot.

The basic Christie-Perry method (15) was used for all routine laboratory determinations involving the separation of nematodes from the soil samples. After thoroughly mixing the moist soil sample, a 150 cc. aliquot was placed in a one-gallon measuring can that tapered toward the top. The soil sample was thoroughly agitated by a water spray that was produced by pinching the distal end of a piece of rubber tubing, which was attached to a water faucet. The contents of the can were rolled to the $\frac{1}{2}$ gallon level, allowed to stand 10 seconds, and decanted onto a nest of sieves. This rolling process was repeated three times for each

sample. Metal sieves, eight inches in diameter, consisted of a 16 mesh top sieve and a 200 mesh, 300 mesh, or nylon parachute fabric retaining sieve on the bottom. After the soil had been washed and decanted three times onto the sieves, they were washed free of colloidal material with a gentle stream of water. The contents of the retaining sieve were washed into the muslin sack of the Baermann funnel, which has been described by Christie and Perry (15). After 24 hours in the Baermann funnel, approximately 4 cc. were drawn from the bottom of the funnel. The nematodes contained in this sample were counted and identified, as far as possible, under a stereoscopic microscope.

Studies on methods of extracting soil nematodes in Experiment IV involved estimates of the variability of the basic Christie-Perry method and a number of modifications of this method.

EXPERIMENT I

THE EFFECT OF CERTAIN CROP ROTATIONS ON NEMATODE POPULATIONS

Materials and Methods

The rotation experiment from which data are reported here was set up at the North Florida Experiment Station, Quincy, in the Spring of 1947. Nematode investigations cover the sixth, seventh, and eighth years of the experiment. Field plots of 1/15 acre size were laid out on virgin Norfolk loamy fine sand, which had a native vegetation predominantly of wire grass. Florida M-1 hybrid corn was grown the first two years and Dixie 18 hybrid corn the remaining years. Dixie Runner peanuts were grown throughout the experiment. Red rustproof No. 1A oats were planted the first three years and Southland oats the last years. Bitter blue lupine was grown the first five years and Alta blue lupine the last years.

The design of the experiment was a randomized block with each rotation replicated four times. The continuous crops and rotation sequences are shown in table 1. The lupine, crotalaria, and oats, in some instances, were turned under for manure. Both oats and vines were removed from the peanut plots. The ears of corn were harvested and the stalks turned under. An explanation of the management practices used in this experiment can be illustrated by selected examples from table 1. Continuous crops, such as peanuts followed by a native cover were planted year after year on the same plot. In a two-year rotation, such as "A", plots 7 and 10 rotate each year so as to have peanuts followed by lupine on the plot one year and corn followed by native cover the next year. For the three-year rotation "A", plots 13, 15, and 17 rotate each year so

TABLE 1

ROTATIONAL SYSTEMS AND PLOT NUMBERS
North Florida Agricultural
Experiment Station
Quincy, Florida

Cropping System		Summer Crop	Winter Crop	Plot Number
Continuous		Peanuts	(native)[1]	1
		Peanuts	(lupine)	2
		Corn	(crotalaria, oats)	3
		Corn	(crotalaria)	4
		Corn	(lupine)	5
		Corn	(native)	6
Two-year rotations		Peanuts	(lupine)	7
	A	Corn	(native)	10
		Peanuts	(lupine)	8
	B	Corn	(velvet beans)	11
		Peanuts	(lupine)	9
	C	Corn	(crotalaria)	12
Three-year rotations		Peanuts	(lupine)	13
		Corn	(lupine)	15
	A	Corn	(oats)	17
		Peanuts	(lupine)	14
		Corn	oats	16
	B	(crotalaria)	(oats)	18

[1] In this table and other tables that appear in this manuscript, parentheses indicate that the enclosed crop is "turned under".

as to have peanuts followed by lupine the first year, corn followed by lupine the second year, and corn followed by oats the third year.

For nematode population studies, approximately one quart of soil was taken from the two yield rows of each plot to a depth of six inches with a one-inch soil sampling tube. Soil samples were taken on April 30, 1952; January 7, June 16, and October 30, 1953; February 6 and July 23, 1954; and January 14, 1955. As experience in accurately identifying nematodes was attained, nematode populations at the various dates were broken down into more precise taxonomic groups, in some cases into genera and species. Only total nematode numbers were obtained for the first three sampling dates. On the October 30, 1953, sampling date, nematode populations of the various plots were broken down into the following groups: Pratylenchus leiocephalus, Criconemoides spp., Hoplolaimus coronatus, Meloidus spp., and miscellaneous nematodes. On this sampling date, nematodes belonging to the superfamily Dorylaimoidea were not separated from the miscellaneous soil inhabiting nematodes because of the poor condition of preservation. The last three sampling dates represent the best practicable separation of taxonomic groups that was possible with the stereoscopic microscope. On these occasions the nematode populations were divided into the following categories: Pratylenchus leiocephalus, Criconemoides spp., Hoplolaimus coronatus, Trichodorus spp., Xiphinema americanum, Meloidus spp., Dorylaimoidea, and miscellaneous nematodes. The group designated as miscellaneous nematodes represent cephaloid and rhabditoid types and an occasional specimen of Aphelenchus sp. In addition to the total nematode counts from the first three

sampling dates, total nematode numbers for each treatment have been computed for other sampling dates by a summation of taxonomic groups.

In processing the soil samples by the Christie-Perry method (15), nematodes from the first four sampling dates were retained on a nylon parachute fabric sieve, otherwise a 200 mesh sieve was used. Except for the first two sampling dates where one-pint soil samples were used, a 150 cc. aliquot was used for the extraction of nematodes

A split plot analysis of variance for the effect of continuous cropping and crop rotation practices on nematode populations was carried out for each of the taxonomic groups. Dates served as main plots and treatments as subplots. On several occasions only three replications were taken from the field plots, therefore only the first three replications from appendix tables were used in the statistical treatment of the data.

In order to obtain data from which generalizations about crop rotations could be made, complementary data from similar rotations in other areas of the state were obtained. On February 6, 1954, soil samples were taken from continuous peanut and corn plots, and a two-year rotation of peanuts at the Marianna Mobile Unit of the North Florida Experiment Station. The soil at this station is Ruston loamy fine sand. On July 21, 1954, soil samples were taken from continuous peanut and corn plots at the West Florida Experiment Station, Jay. The soil on which these plots are located is a Red Bay fine sandy loam. Nematological examinations of samples from both of these locations were handled in the same manner as those of the major rotation study at Quincy.

Results and Discussion

The prevalent plant parasitic nematode found in the soil from the rotation experiment at Quincy was the smooth-headed meadow nematode, Pratylenchus leiocephalus Steiner, 1943. Found in smaller numbers were ring nematodes, Criconemoides spp.; lance nematodes, Hoplolaimus coronatus Cobb, 1923; stubby root nematodes, Trichodorus spp., and dagger nematodes, Xiphinema americanum Cobb, 1913. Repeated examination of soil samples failed to reveal the presence of root-knot nematode larvae or males.

Treatment differences for meadow nematodes over the four sampling dates are highly significant (table 2) with a L. S. D. at 5 percent probability of 88.2. Significantly larger numbers of meadow nematodes occurred following corn in the continuous cropping practices and the three-year rotation, than were found following peanuts. No significant differences occurred between corn and peanuts in the two-year rotation. Apparently corn is the preferred host for meadow nematodes, while peanuts do not provide conditions favorable for the reproduction of this organism. This assumption is further verified from trends that become apparent after examining the data in table 2. The largest populations of meadow nematodes occurred in the continuous corn treatments. The three-year rotation in which corn is grown two out of three years has the next largest population, while in the two-year rotation where peanuts depress the population every other year, the meadow nematodes were considerably reduced in numbers. In addition, at the West Florida Experiment Station (Jay) continuous corn had significantly larger meadow nematode populations than continuous peanuts (table 3). Though not significant, the corn trend was observed in studies from rotations at the Marianna Mobile Unit (Table 6).

TABLE 2

EFFECT OF CROP ROTATION AT FOUR SAMPLING DATES ON THE NUMBERS OF *PRATYLENCHUS BRACHYURUS* [1]
QUincy, Florida

Cropping System	Date Oct. 30 1953	Feb. 6 1954	Jul. 23 1954	Jan. 14 1955	Treat. Av.
Continuous:					
Peanuts (native)	4.3	2.7	2.0	0.7	2.4
Peanuts (lupine)	10.7	3.3	3.7	0.7	5.1
Corn (native)	139.3	98.7	264.7	25.7	132.1
Corn (lupine)	368.0	61.3	403.0	37.0	217.3
Two-Year Rotation					
Peanuts (lupine)	14.3	5.0	8.0	2.0	7.3
Corn (native)	70.7	28.3	15.7	2.7	29.3
Three-Year Rotation					
Peanuts (lupine)	8.3	3.7	22.7	3.3	9.3
Corn (lupine)	238.3	109.7	43.0	11.3	104.1
Corn (oats)	186.7	80.0	175.3	20.3	116.1
Date Av.	177.4	43.5	104.4	11.5	

Treatment L. S. D. .05 - 88.2; Date L. S. D. .05 - 30.5
Date X Treatment interaction - highly significant

[1] Each entry in the table is an average of the values of the first three replications for each treatment from appendix tables I - IV.

TABLE 3

EFFECT OF CROP ROTATION ON PRATYLENCHUS LEIOCEPHALUS NUMBERS
JAY, FLORIDA
July 21, 1954

Cropping System	Replications			Av.
	2	3	4	
Continuous:				
Peanuts (native)	3	5	1	3.0
Peanuts (lupine)	9	3	5	5.7
Corn (native)	84	123	58	88.3
Corn (lupine)	136	90	68	98.0
Treatment L. S. D. .05 -				46.7

Equally, the effect of cover crops on nematode populations could be best studied in a continuous cropping practice where there are no confounding effects from the rotation of cash crops. Differences in meadow nematode populations were not significant between lupine, native and oat covers in any rotation (tables 2 and 3); however, constant trends appear. Lupine and oats appear to support a larger population of meadow nematodes than native cover. Poor stands of lupine, particularly after continuous peanuts, have occurred since the first year of the experiment.[1] In the Quincy area, native cover was so sparse so to approach a fallow following peanuts. Very poor stands and subsequent poor growth occurred when lupine followed continuous peanuts; therefore, significant differences between native and lupine cover will be difficult to establish. Lupine yields were slightly higher after continuous corn, and to some extent, this was reflected in trends of larger numbers of meadow nematodes in the continuous corn plots that were followed by lupine cover. Lupine yields were higher in three-year than in two-year rotations, but due to the design of this experiment there was no comparison of this cover crop with native cover in a long rotation.

An interaction exists between sampling dates and treatments (table 2). This interaction is found in the three-year rotations where the October and February sampling dates had considerably higher numbers of meadow nematodes for corn followed by lupine than for corn followed by oats as compared with the July and January sampling dates where the larger population occurred

---

[1] Additional information on the effect of rotations, fertilizer, lime and cover crops on yield from these studies has been published by Thompson and Robertson (91).

in the corn plots. Due to this interaction, significance is probably lost; however, the data show a trend for higher meadow nematode numbers in plots where oats were grown.

Other plant parasitic nematodes were present in smaller numbers (appendix tables V - XVIII). Populations of Hoplolaimus coronatus, Trichodorus spp., and Xiphinema americanum from the rotation at Quincy behaved similarly to Pratylenchus populations in that peanuts supported significantly lower numbers of these parasites than corn (table 4). From the single sampling of the Marianna rotation, Xiphinema americanum appeared in significantly higher numbers in the corn (oats) plots than corn (native) and corn (lupine) plots (table 6). From the data it appears that corn is the preferred host for lance, stubby-root, and dagger nematodes. The largest populations were supported by continuous corn and the smallest by corn in the two-year rotation, while intermediate numbers occurred in the three-year rotation where corn was grown two out of three years. The influence of cover crops on populations of Hoplolaimus coronatus and Xiphinema americanum is of interest because significantly lower numbers occurred in the continuous corn (lupine) plots than in continuous corn (native) plots (table 4). In the case of Xiphinema americanum, data from the Marianna rotation (table 6), though not significant, supplement the Quincy data in that native cover had a tendency to support larger numbers of lance nematodes than lupine. Differences in Trichodorus spp. numbers for cover crops were not significant (table 4). An interaction exists for Trichodorus spp. numbers between cover crop dates and treatments. This interaction is associated primarily with inconsistencies in population responses to cover crops (appendix tables XII - XV).

TABLE 4

EFFECT OF CROP ROTATION ON NUMBERS OF SEVERAL GENERA OF SOIL NEMATODES[1]
QUINCY, FLORIDA

	Belonolaimus longicaudatus	Trichodorus spp.	Xiphinema americanum	Meloidogyne spp.	Paratylenchus	Miscellaneous Nematodes	Total Nematode Numbers
No. sampling dates	4	3	3	4	3	4	7
Cropping Systems							
Continuous:							
Peanuts (native)	0.8	0.0	0.8	0.2	15.6	94.0	87.5
Peanuts (lupine)	0.4	0.0	0.3	0.1	24.1	125.8	122.3
Corn (native)	9.3	17.2	27.9	7.4	89.7	354.3	497.9
Corn (lupine)	6.3	21.9	4.0	3.5	74.6	343.1	559.6
Two-year rotation							
Peanuts (lupine)	0.2	2.7	1.4	2.0	29.3	321.9	264.3
Corn (native)	0.7	3.1	2.4	2.0	24.8	374.6	316.2
Three-year rotation							
Peanuts (lupine)	0.5	2.8	0.3	0.8	49.3	213.7	248.6
Corn (lupine)	0.7	10.1	1.2	3.0	46.0	409.0	403.0
Corn (oats)	0.8	22.8	7.4	3.0	58.0	370.9	407.1
[illegible] .05	2.8	13.4	17.2	3.2	21.0	235.4	67.8
Date significance	n.s.	**	n.s.	**	**	*	**
D X T [illegible]	[illegible]	*	n.s.	n.s.	**	[illegible]	**

[1] Each treatment value in the table is an average of the first three replications from appendix tables for the respective group of nematodes.

Ring nematodes, Criconemoides spp., are of particular interest because their host preference differs from that of meadow, lance, dagger, and stubby-root nematodes. In contrast to the other plant parasitic nematodes, ring nematode populations were larger on peanuts that on corn (tables 5 and 6). Significantly larger populations occurred where continuous peanuts were grown than where continuous corn was grown. No significant difference in numbers existed in the two-year rotation where corn depressed the population every other year. In the three-year rotation, the population on peanuts was slightly higher, but not significantly so, than on corn. In this case, lack of significance is not surprising because the preferred host, peanuts, was grown only once in three years. Additional evidence on the susceptibility of peanuts to ring nematodes is found in the significantly larger population in July when peanuts were on the plots (table 5). Examination of treatment averages in the continuous crops and three-year rotation (table 5) indicates that there was a tendency for lupine to support a larger Criconemoides population than native cover; however, from the one sampling date of the rotation at Marianna, this tendency did not exist. An interaction exists between dates and treatments. This interaction is located primarily in the two-year rotation where at the July and January dates corn had more ring nematodes than peanuts, and at the October and February dates larger populations occurred on peanuts than on corn (table 5).

Ring nematodes are the only plant parasitic nematodes that can be associated with peanut yields. A large number of Criconemoides, particularly at the peanut growing season, can associated with the low yielding continuous peanuts. Also, Criconemoides were associated with low yields

TABLE 5

EFFECT OF CROP ROTATION AT FOUR SAMPLING DATES ON THE NUMBERS OF CRICONEMOIDES SPP.[1]
QUINCY, FLORIDA

Cropping Systems	DATE				
	Oct. 30 1953	Feb. 6 1954	Jul. 6 1954	Jan. 14 1955	Treat. Av.
Continuous:					
Peanuts (native)	1.3	2.7	30.3	16.3	17.0
Peanuts (lupine)	0.3	0.3	56.3	17.0	18.5
Corn (native)	1.7	0.7	9.0	4.7	4.0
Corn (lupine)	3.0	1.0	11.0	3.0	4.5
Two-year rotation					
Peanuts (lupine)	0.7	1.3	5.3	11.0	5.1
Corn (native)	0.3	0.0	10.3	11.3	6.5
Three-year rotation					
Peanuts (lupine)	8.7	2.7	11.0	5.7	7.0
Corn (lupine)	0.7	0.3	7.7	3.0	3.9
Corn (oats)	0.3	0.3	1.7	1.7	1.0
Date Av.	2.1	8.1	18.1	8.0	

Treatment L. S. D. .05 - 9.1; Date L. S. D. .05 - 3.6
Date X Treatment interaction - highly significant

[1]Each entry in the table is an average of the values of the first three replications for each treatment from appendix tables V - VIII.

TABLE 6

EFFECT OF CROP ROTATION ON NUMBERS OF SOIL NEMATODES
MARIANNA, FLORIDA[1]
February 6, 1954

Cropping System	Pratylenchus brachyurus	Criconemoides spp.	Xiphinema americanum	Meloidogyne spp.	Paratylenchus spp.	Miscellaneous nematodes	Total nematode numbers
Continuous:							
Peanuts (native)	6.0	1.7	0.3	0.3	13.7	102.7	124.7
Peanuts (lupine)	4.7	0.3	0.7	0.3	6.7	61.0	74.0
Peanuts (oats)	3.7	0.0	0.0	0.3	8.0	158.3	170.7
Corn (native)	85.3	0.0	11.0	4.7	22.3	340.3	405.0
Corn (lupine)	11.7	0.0	5.3	0.7	22.7	452.7	493.0
Corn (oats)	12.0	0.0	43.0	4.0	38.0	635.7	732.7
Two-year rotation							
Peanuts (native)	5.0	0.3	0.0	1.0	19.0	363.0	388.7
Corn (native)	30.7	0.0	1.3	0.3	18.0	431.0	481.3
[illegible]	n.s.	n.s.	n	n.s.	n.s.	n	n
C. V. %	28		31.6			35.3	39.6

[1]Each value is an average of three replications taken from appropriate appendix tables.

of peanuts from plots that followed lupine cover crops. Over the eight year period of the Quincy rotation experiment, continuous peanuts (native) plots have yielded more nuts than continuous peanuts (lupine) plots. Larger yields have been obtained from the two- and three-year rotations. The longer rotation produced the highest yield. These high yields were associated with small numbers of ring nematodes.

the collective group of nematodes referred to as miscellaneous nematodes are organisms associated with decay, therefore, it would be expected that they would be associated with soil organic matter. Soil organic matter was higher in treatments where corn was grown than in peanut treatments. the highest organic matter was found in the three-year rotation, lowest in continuous cropping practices, and intermediate in the two-year rotation (31). Significantly higher numbers of miscellaneous saprophytic nematodes occurred where corn was grown than where peanuts were grown. In addition, saprophytic nematodes occurred in largest numbers in the three-year rotation, smallest numbers in the continuous cropping practices, and intermediate numbers in the two-year rotation (table 4). Thus, miscellaneous soil nematodes were associated with soil organic matter content.

Nematodes belonging to the superfamily Dorylaimoidea are considered carnivorous, saprophagous, or plant parasitic. Xiphinema americanum and Trichodorus spp. are the only definitely known plant parasitic nematodes of this superfamily that occurred in the soil of this rotation study, and these have been separated from the designated group Dorylaimoidea that appears in the tables. the most commonly

occurring genera of the Dorylaimoidea group were Discolaimus, Dorylaimus, and Aporcelaimus; although other genera frequently occurred. In contrast to the miscellaneous nematode group, Dorylaimoidea populations did not correlate with the amount of soil organic matter, but with crops and rotation. For the continuous crops, soil from the peanut plots had significantly lower numbers than the corn plots. Soil from the continuous corn plots had significantly higher numbers than corn in the two- and three-year rotations. The two-year rotation had smaller numbers than the three-year rotation (table 4). From these data it appears that the bulk of Dorylaimoidea show the same response to crops and rotation as the plant parasites, i.e., Pratylenchus, Hoplolaimus, and Trichodorus. Though not as complete and obvious, similar observations are indicated in data from the Marianna rotation (table 6). It would not be unreasonable to deduce that most of the Dorylaimoidea involved in this study are plant parasitic; although there certainly remains a possibility that these organisms are carnivores of oligochaetes, of plant parasitic and of miscellaneous nematodes, or of other soil organisms.

Nematodes belonging to the genus Mononchus are predators of many soil organisms, including nematodes; therefore, they play a role in the biological control of plant parasitic nematodes. In the rotations at Quincy and Marianna, mononchs were present in small numbers (tables 4 and 6), and if the population size is any indication, their importance to biological control of plant parasitic nematodes is limited. However, they were found in largest numbers in treatments that had a high nematode population.

During the initial stages of this investigation, total nematode determinations were made for all continuous cropping practices and rotations at Quincy. Data from the first three sampling dates are practically meaningless in that differences existed only between corn and peanuts, particularly between continuous corn and peanut crops, (appendix tables XXX - XXXIX). Total nematode numbers for the seven sampling dates showed little more (table 4). However, a tendency does exist for the total nematode population to follow the fluctuations of the plant parasitic nematode populations. Lack of reliable differences between treatments for total nematode numbers arises from including the miscellaneous saprophagous nematodes in this group. Other than indicating the role of nematodes in soil microorganism dynamics, total nematode counts have little meaning because they do not reveal the nature of the various groups. For example, the total nematode count may be high, yet few plant parasites may be present. Soil samples with almost pure cultures of saprophagous nematodes are often encountered.

Another important consideration in any study of nematode population dynamics is seasonal development of the population. Significant differences between dates occurred for Pratylenchus leiocephalus, Criconemoides spp., Trichodorus spp., Meloidae spp., Rotylenchoides, miscellaneous nematodes, and total nematode numbers (tables 2, 4, and 5). The total nematode population was at a low level during the winter, but started to rise during the spring and continued through the late summer and early fall until it reached a high peak in October (appendix tables XXX - XXXVI). Only generalizations can be made about the various

nematode groups because of the limited number of observations during the seasons. For Criconemoides spp., Trichodorus spp., and Dorylaimoidea high peaks in the population occurred in July while lower populations were found in the colder seasons. The number of Pratylenchus leiocephalus was low during the winter, and increased during late summer, reaching a high point in October (appendix tables I - IV). Mesocriconema spp. and miscellaneous nematodes showed rather erratic behavior in that high populations occurred in October and February, and low populations occurred in July and January. Seasonal differences and similarities suggest several important considerations. The predaceous mononch populations correlate with the group of organisms that comprise most of the soil nematode population, the miscellaneous nematodes; therefore the latter group must serve as the major source of food for the mononchs. The Dorylaimoidea correspond to the plant parasites, especially Criconemoides spp. and Trichodorus spp. This, in addition to response to crop management practices, indicates that the bulk of the Dorylaimoidea from the Quincy rotation may feed on plants.

EXPERIMENT II

THE RELATIVE BUILD UP OF SOIL NEMATODES OF SELECTED COVER CROPS

Arredondo fine sand was used in this experiment. The soil was fumigated in a 55 gallon oil drum that could be sealed with a gasket lined top and a compression ring. Moist soil was placed in the drum in six-inch layers. Each layer received 3 cc. per square foot of 40 per-cent dichloropropane-dichloropropene ("DD"). The sealed drum was allowed to stand 10 days before its contents were spread on a greenhouse bench to aerate for three weeks. After aeration a representative sample was taken, moistened, and after several days, checked for nematodes. The soil in which legumes were to be grown received the equivalent of 600 pounds per acre of $Ca(OH)_2$ and 600 pounds per acre of 0-10-20 fertilizer. The soil in which sweet corn was to be grown received $Ca(OH)_2$ at the rate of 600 pounds per acre and 4-5-7 fertilizer at the rate of 1200 pounds per acre. These materials were thoroughly incorporated into the soil prior to planting. Plants were grown in six-inch clay pots containing 1250 cc. of air dry soil. The pots were placed on benches in a greenhouse.

The treatments consisted of six winter legumes and the reference plant, Aristogold sweet corn, with five replications in a randomized block design. The legumes comprised common ones that are likely to be used as winter cover crops in Florida. These included Hubam sweetclover, sweet yellow lupine, bitter blue lupine, vetch, Austrian winter pea, and Dixie crimson clover. Seeds were planted in the pots on January 22, 1954. The legume seeds were inoculated with appropriate Rhizobium species. On February 2, 1954, the plants were thinned to three per pot,

and two blocks of plants were inoculated with 50 hand picked specimens of Belonolaimus gracilis Steiner, 1949, per pot. The last two blocks were inoculated on February 4, 1954. The nematodes were washed into a small hole of approximately one cubic inch that was located between the three plants, and then covered with soil.

Starting on April 13, 1954, sting nematode counts were made on soil from around the roots of the plants in each pot. One block a day was processed until all had been examined. Three separate laboratory determinations were made of sting nematode numbers in each pot, making a total of 21 examinations each day. The soil around the roots was thoroughly mixed and passed through a 5 mm. sieve. Using a 150 cc. soil sample, the nematodes were extracted from the soil by the Christie-Perry method (15) in which the nematodes were retained on a 100 mesh sieve. An average number of nematodes per pot was calculated, and an analysis of variance was carried out to determine significance between treatments.

Results and Discussion

No nematodes were found in the soil after fumigation with DD.

Ten weeks after inoculation with sting nematodes significant differences in the number of nematodes on the various plants were detected (table 7). The soil in which vetch, sweet corn, and Dixie crimson clover were growing had significantly larger numbers of sting nematodes than were found in the soil where bitter blue lupine was growing. Of the legumes, vetch and Dixie crimson clover favored the development of the sting nematode more than bitter blue lupine, Nikom, and sweet yellow lupine.

TABLE 7

RELATIVE NUMERICAL INCREASE OF PSEUDOSARINA CRACCIVORA ON SEVERAL WINTER LEGUMES AND SWEET CORN

Crops	Replications					Av.	Reproductive Rates
	1	2	3	4	5		
Bitter Blue Lupine	8.0	1.7	2.7	6.0	2.0	4.1	0.8
Rhem	7.0	15.0	7.3	10.0	4.3	8.7	1.7
Sweet Yellow Lupine	9.7	7.0	10.6	17.0	5.5	10.0	1.9
Austrian Winter Pea	13.0	11.7	25.3	19.7	9.0	15.7	3.0
Dixie Crimson Clover	12.0	17.0	15.7	33.3	43.3	24.3	4.6
Aristogold Sweet Corn	36.0	32.0	25.5	55.6	84.0	48.7	9.4
Vetch	27.7	34.0	74.7	44.3	96.3	55.4	10.7
					Significance L. S. D. .05	** 18.3	

Observations indicate that there was little injury to the roots, except that small brown lesions were noted on the roots of sweet yellow and bitter blue lupine.

Initially there were 5.2 sting nematodes per 150 cc. of soil in each pot. Dividing the average number of nematodes recovered in 150 cc. of soil by 5.2 gives the multiplication or reproductive rate of sting nematodes on the various crops (table 7). A reproduction rate of 1.0 would indicate that the particular plant maintained the original population, as was the case for bitter blue lupine. The reproductive rate for Rebun, sweet yellow lupine, Austrian winter peas, and Dixie crimson clover indicates that the number of sting nematodes on these plants increased during the 10 week period of the experiment. The reproductive rate of sting nematode on sweet corn and vetch clearly show that the populations built up rapidly in the presence of these plants.

Corn was used in this experiment as a reference plant because of the known susceptibility of this plant to the sting nematode. The data in table 7 indicate the response of winter legumes and sweet corn to sting nematodes under greenhouse conditions; therefore the build up of sting nematodes under winter field conditions would not be expected to be as large as those exhibited here. The build up on corn may be indicative of what would happen under summer field conditions. Future research may prove that a highly resistant winter cover crop is not absolutely necessary in order to prevent increases in ectoparasitic plant nematodes because of low temperatures during the winter, particularly in colder areas. On the basis of this experiment, however,

vetch nor possibly Dixie crimson clover should not be planted in areas where sting nematodes are already established.

The methods used in this experiment are of greater importance than the findings themselves. The method outlined here permits the rapid screening of large numbers of plants for future field trials. In comparison to preliminary field screening tests, this method requires only a small expenditure of time and energy. This type of experiment is not designed to test the capacity of a given nematode to inflict damage to the host, in fact, lack of serious host injury is preferred because a stunted or sickly plant is likely to produce less food material for the parasitic nematode population. Plants in a serious state of decline are known to support smaller populations of plant parasitic nematodes than healthy plants that have not begun to show symptoms of nematode infestation. Therefore, the nematode inoculum in tests to determine the rate of build up of parasitic nematode populations should be small, yet large enough to give an adequate distribution curve at the termination of the experiment. In this experiment an inoculum of 50 sting nematodes fulfilled these requirements.

It is important to include a reference plant in each experiment so that adjustments can be made for variations in conditions between experiments that influence nematode populations, thereby allowing comparisons between plants grown at different times. Sweet corn makes an excellent reference plant for many field and vegetable plants because of its cultural nature.

EXPERIMENT III

EFFECTS OF SOIL FERTILITY LEVELS ON PLANT PARASITIC NEMATODE POPULATIONS

Materials and Methods

To test the relationship of plant parasitic nematodes to soil fertility, sixteen field plots were laid out on Leon fine sand at the Central Florida Experiment Station, Sanford. Each plot was 10 x 43 feet or 1/100 acres. Four treatments consisted of control, low, medium, and high fertility levels. Each treatment was replicated four times in a completely randomized design.

These plots had been previously cropped to kenaf. The kenaf stubble was disked under on February 26, 1954. This area had not been fumigated for nematode control.

Michael-Leonard's Aristogold Bantam Evergreen sweet corn was planted on March 12, 1954, in 30-inch rows. The four treatments consisted of the control with no fertilizer; the low fertility level with a total of 1000 pounds per acre of 4-5-7 fertilizer; the medium fertility level with a total of 2000 pounds per acre of 4-5-7 fertilizer; and the high fertility level with a total of 3000 pounds per acre of 4-5-7. Each plot received one-third of the total amount of fertilizer on April 6, 1954; one-third on April 21, 1954, and the final third on May 17, 1954. On May 26, 1954, the two center rows of each four-row plot were harvested, thus the yield from 1/200 acre was harvested from each plot. The number of plants, number of ears, and total weight of ears from each plot was recorded. Nematode counts were made on March 17,

1954, for each plot prior to the planting of sweet corn. Nematode counts were made on June 2, 1954, following the harvest of the corn. The corn stover was disked under later that same day, and native vegetation was allowed to grow on the plots until the beginning of the celery season when it was disked under.

Analysis of variance was made on the data for weight of corn, number of corn, and plant parasitic nematodes. Inasmuch as plant parasitic nematodes probably influenced the number of plants and weight of corn, and to some extent the number of corn, a "yield factor" was devised which would give a yield index value that is related to numbers of plant parasitic nematodes. An analysis of variance was calculated for the yield factor, number of corn times weight of corn divided by number of plants.

Celery was planted on October 1, 1954, in 30-inch rows. Celery seedlings were secured from fumigated seedbeds. No fertilizer was applied at the time of transplanting. The fertilizer levels for celery were no fertilizer and two, three, and five tons of 5-5-5 fertilizer per acre divided into two applications which were made at 10-14 day intervals. The various fertilizer levels were placed on the same plots that had previously received a comparable fertility level for corn; for example, plots that received no fertilizer in the corn experiment were not fertilized in this experiment. Celery from the two center rows of each four-row plot was cut and weighed on February 1, 1955. The weight of blanchedt-stalks and total weights were recorded. On February 8, 1955, representative root samples were dug from the two center rows of

each plot and washed free of soil. The number of roots and their oven dry weights (70°c) were recorded. Nematode counts were made mid-way in the celery growing season on December 9, 1954, and following harvest on February 8, 1955.

Analysis of variance was calculated for celery stalk weights, average root weights, and numbers of plant parasitic nematodes.

For both corn and celery, soil samples for nematode studies consisted of one quart soil samples taken from the root zone of the two center rows. The plots were sampled with a standard one-inch soil sampling tube to a depth of six inches. Laboratory determinations were made on a 150 cc. aliquot from each quart container. The Christie-Perry method (15) of extracting nematodes was used. The nematodes were retained on a 200 mesh sieve. Laboratory determinations were made in duplicate for the February 8, 1955, sampling date, and the average values recorded. For the December 9, 1954, sampling date, single laboratory determinations were made.

Results and Discussion

On March 17, 1954, at the beginning of the corn growing season Dolichodorus heterocephalus and Trichodorus spp. numbers were low. The largest number of plant parasites found on any one plot was five per 150 cc. of soil. Data plots had zeros (appendix table XXXVIII). On March 17, 1954, significant differences in treatments did not occur for either D. heterocephalus or Trichodorus spp. (table 8). During the period that corn was on the plots, the plant parasitic nematode populations increased considerably. On June 2, 1954, at the conclusion

TABLE 8

NEMATODE COUNTS FROM SWEET CORN
AT VARIOUS FERTILITY LEVELS

Treatments: lbs. per acre 4-5-7 fertilizer	Heterodera heterocephalus		Trichodorus spp.	
	Mar. 17, 1954	June 2, 1954	Mar. 17, 1954	June 2, 1954
0	0.8[1]	8.3	0.3	12.8
1000	1.3	19.5	0.8	28.5
2000	1.3	11.8	1.5	34.5
3000	1.5	32.2	0.0	85.8
Significance	n.s.	*	n.s.	n.s.
L. S. D. .05	-	19.3	-	-

[1]Each table entry is an average of 4 replications from appendix table XXXVIII.

of the season, as many as 50 specimens of D. heterocephalus and 172 specimens of Trichodorus spp. occurred in 150 cm. of soil from certain plots (appendix table XXXVIII). By June 2, 1954, the number of D. heterocephalus in the high fertility plots was significantly higher than the check plots that received no fertilizer (table 8). the same significance for Trichodorus did not occur; although, significance was approached.

From the sweet corn yield data (table 9), it is interesting to note that even though significantly more ears were harvested from the highest fertility level, there was no significant increase in the total weight of ears above 1000 pounds per acre of 4-5-7 fertilizer; conversely, there was an apparent decrease in total ear weight per plot with increases in fertility through 3000 pounds per acre of 4-5-7 fertilizer. No significance was found for the average ear weight or yield factor for the various fertility treatments (table 9).

Formulation of the yield factor represents an attempt to place a numerical value on the overall influence of plant parasitic nematodes on factors that influence the vegetative response of corn at different fertility levels. This arbitrary factor is of little value in interpreting the data because it lacks significance. Of the other values, the total weight of corn harvested from the plots probably represents the best vegetative measure of plant response to fertility and effect of nematode damage to roots. A restricted root system will be less effective in absorbing nutrients from the soil than a healthy one. the number of plots parasitic nematodes in the soil should be related to the

TABLE 9

SWEET CORN YIELD DATA FROM VARIOUS FERTILITY LEVELS
SANFORD, FLORIDA

Treatments: lbs. per acre 4-9-7 fertilizer	Wt. Ears (lbs.)	No. Ears	Av.Wt. per Ear (lb.)	Yield Factor: No.Ears X Wt.Ears / No. Plants
0	4.4[1]	10.5	0.35	1.84
1000	16.0	28.8	0.56	17.31
2000	15.9	31.8	0.49	17.58
3000	15.1	35.3	0.57	20.94
Significance	**	**	n.s.	n.s.
L. S. D. .05	8.3	12.7	-	-

[1]Each table entry is an average of 4 replications from appendix table XXXVII.

vegetative response of the plant, in this case, the weight of the corn. The data bear this out, for as the fertilizer was increased from the check to the 1000 pounds per acre of 4-5-7 there was an increase in the number of parasitic nematodes. this was probably due to the presence of a more extensive root system which supported a larger nematode population. As the plant parasitic nematode population increased with fertility, there was an apparent reduction in the weight of corn ears. It is entirely possible, and in fact probable, that during the 83 days that corn was on the land, parasitic nematodes became a limiting factor in production, and further additions of fertilizer would not have resulted in an economic increase in yield.

Of greater interest are the relationships between plant parasitic nematode numbers, fertility levels, and celery yield data. Celery yields significantly increased with fertility levels through the three tons per acre rate of application of 5-5-8 fertilizer, but sharply declined at the five-ton application rate (table 10). Maximum root development occurred at the one-ton rate and not at the three, as might be expected from celery yield data (table 10, figure 1).

At this point, field observations add considerably to the importance of these findings. Celery that received no fertilizer had a rather well developed root system in proportion to its top size. the root system of these plants was fibrous and extended well down into the soil. In contrast, roots from plants growing under higher fertility conditions showed more necrosis and more of the classical stubby-root condition. Roots from the low fertility level, one-ton fertilization

TABLE 10

CELERY YIELD DATA FROM VARIOUS FERTILITY LEVELS
SANFORD, FLORIDA

Treatments: tons per acre 5-5-5 fertilizer	Av. Total Yield per Plot (lbs.)	Av. Root Wt. per Plant (gms.)
0	31.5[1]	4.3
1	187.0	12.7
3	367.5	8.3
5	294.0	9.8
Significance	**	**
L. S. D. .05	72.3	3.2

[1] Each table entry is an average of 4 replications from appendix tables XXXIX and XL.

rate, were by far the largest of all the treatments, but they did not penetrate into the soil as far as those of the more vigorous control plants. With higher fertility levels, three- and five-ton fertilization rates, the amount of stubbing increased, and the roots became restricted to the upper three or four inches of surface soil. Plot number 16 (appendix table XLX) was a high fertility plot, and several areas in this plot, even with adequate fertility, produced plants that were scarcely larger than the controls. On December 9, 1954, nematode counts were made on soil from around the roots of these poor plants and from soil around adjacent superior plants. A 150 cc soil sample from the superior area contained 192 awl and 103 stubby-root nematodes, while a corresponding soil sample from the adjacent poor area contained 946 awl and 389 stubby-root nematodes. This indicates that parasitic nematode populations can be of such magnitude that yields, even in the presence of high fertility, are markedly reduced.

Applications of fertilizer every 10 - 14 days supplied a continuous source of nutrients for plant development. As the number of fertilizer applications increases, root proliferation should increase. Accordingly, root growth should be faster at the higher fertility levels. Plant parasitic nematode populations should also increase because of a more abundant food supply. Though not significantly different, numbers of D. heterocephalus and Trichodorus increased with fertility levels at the December 9, 1954, sampling date, which was approximately halfway through the growing season (table 11, figure 1). Nematode numbers should decline as the plants approach maturity because mature plants

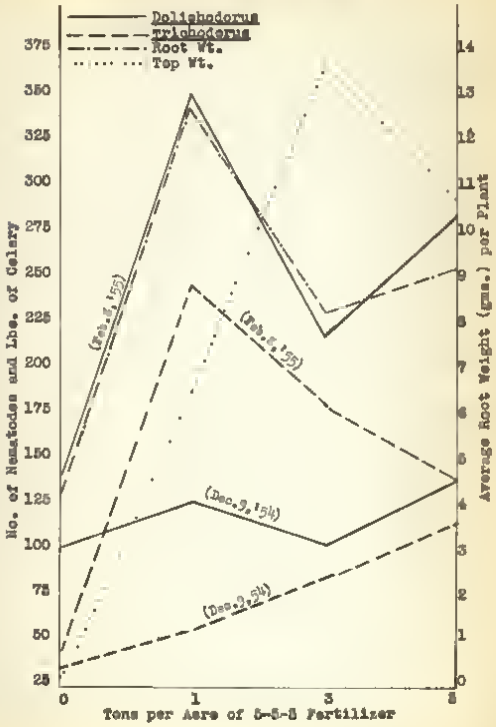
TABLE 11

NEMATODE COUNTS FROM CELERY AT VARIOUS FERTILITY LEVELS SANFORD, FLORIDA

Treatments: tons per acre 5-8-8 fertilizer	Rotylenchorus heterocephalus		Trichodorus spp.	
	Dec. 9, 1954	Feb. 8, 1955	Dec. 9, 1954	Feb. 8, 1955
0	103.3[1]	144.6	35.5	39.8
1	127.8	349.9	62.3	247.1
3	104.5	218.3	86.5	188.3
5	144.8	200.0	115.3	146.9
Significance	n.s.	n.s.	n.s.	**
L. S. D. .05	-	-	-	76.0

[1] Each table entry is an average of 4 replications from appendix table XLI.

FIGURE 1
EFFECT OF FERTILIZER ON YIELD OF CELERY TOPS AND ROOTS
AND ON NEMATODE POPULATIONS



put and new roots less rapidly than young vigorous plants. Recession of plant parasitic nematode numbers should occur first at the higher fertility levels because the parasites reach damaging proportions at an earlier date under these conditions than on slowly growing plants of lower fertility levels. Actual nematode counts from the various fertility levels at the end of the celery growing season substantiated these hypotheses (table 11, figure 1). Numbers of P. heterocephalus and Trichodorus increased between the plots that received no fertilizer and the one-ton fertilization rate, and decreased at higher fertility levels. Significance for Trichodorus populations existed between the control, which was not fertilized, and the higher fertility levels (table 11).

Additional informative relationships on nematode population dynamics are discernible in the relative differences in the size of the populations between the two sampling dates for the four fertility treatments (table 12).

These relative increases further indicate that the number of plant parasitic nematodes must have attained a high peak in the high fertility plots at an earlier time and were in a state of decline at the last sampling date. Where one-ton of fertilizer was used, plant parasitic nematode populations were at or near a high peak. Treatments that did not receive fertilizer applications were probably at the top of a low amplitude population peak and will never produce populations as large as those from the higher fertility levels.

Still another explanation of the decrease in nematode populations

TABLE 12

RELATIVE NUMERICAL INCREASE OF NEMATODE POPULATIONS BETWEEN DECEMBER, 1954, AND FEBRUARY, 1955

TREATMENTS	NEMATODES	
Tons of Fertilizer per acre	Heliocotylenchus heterocephalus	Tylenchorhynchus spp.
0	41.5[1]	4.5
1	222.1	104.8
3	113.8	94.8
5	143.2	31.6

[1]Each entry is the difference between numbers at the December 9, 1954, and February 8, 1955, sampling dates taken from table 11.

at the higher fertility levels is the toxic effects of heavy applications of fertilizer. However, due to the limited evidence at hand, this assumption remains problematical and requires further experimentation for positive proof.

Figure 1 shows that for the conditions of this experiment, the celery root weight curve follows closely that of the nematode populations at harvest time. Root weights decreased above the one-ton fertilization rate while celery top weights continued to increase through the three-ton fertilization rate at which point it decreased. Inasmuch as celery yields increased through the three-ton rate, additions of fertilizer up to this point apparently allow increases in celery yield despite high nematode populations and restricted root development. The decline in celery yield at the five-ton fertilization rate may very well be associated with some other cause than nematodes, e. g., nutrient balance. Reduction in celery yields occurs frequently at a fertilization rate of five tons per acre of 5-5-8 fertilizer in the Sanford area, even on fumigated land.

EXPERIMENT IV

AN EVALUATION OF THE CHRISTIE-PERRY MODIFICATION OF THE BAERMANN FUNNEL TECHNIQUE WITH SEVERAL NEW INNOVATIONS ON ITS USE

Materials and Methods

In this experiment several separate sub-experiments were carried out to evaluate the commonly used Christie-Perry method of separating nematodes from the soil. This was done in an effort to locate sources of error in the method, and on the basis of the findings to make modifications and suggestions regarding its use. The statistical measure of the "coefficient of variability"[1] was used in these studies because the usefulness of any laboratory method in quantitative experimental studies is determined by the variability inherent in the method itself.

Nematode infested soil was placed in seed flats and planted with Everglades No. 1 Bermuda grass. Soil from these flats contained a readily available supply of plant parasitic and miscellaneous soil nematodes. The soil itself was a composite of the top soil from Leon fine sand and Arredondo fine sand. For each sub-experiment, an excess of the required amount of soil was brought into the laboratory and sifted through a 5 mm. metal sieve to remove the grass roots, and mixed until a homogeneous soil was obtained. All determinations were made on 100 cc. soil samples of this homogeneous soil. Nematodes were identified and counted under a stereoscopic microscope.

---

[1] Coefficient of variability = S. V. = $\frac{\text{S.D.}}{\text{Mean}} \times 100 = X\,\%$

A. Variability of the Baermann funnel.

Each 150 cc. soil sample was rolled with a water spray to the ½ gallon level of the previously described one gallon measuring can and decanted onto a nest of sieves. The top sieve was of 1 mm. mesh, and the retaining sieve 100 mesh. This rolling and decanting process was repeated three times. After the colloidal particles had been washed through the retaining sieve, the contents of this sieve were washed into the muslin sack of the Baermann funnel, which had been previously filled with tepid water (30°C). Sixteen funnels were set up in this manner with careful attention being given to constancy in processing each sample. After 24 hours a 4 cc. sample was drawn from each funnel and nematode counts made. Additional 4 cc. samples were drawn after 48 and 72 hours. the number of sting, sol, and miscellaneous nematodes were recorded for each sample. On the basis of 16 samples, the coefficients of variability for the means of the above nematode groups were computed for the counts made after 24, 48, and 72 hours. the nematode values for 48 hours represent the summation of the numbers recovered after 24 and 48 hours; likewise values for 72 hours are a summation of the numbers recovered after 24, 48, and 72 hours.

the average number of nematodes remaining in the muslin sack after 72 hours of extraction was determined by washing the contents of the sack into a petri dish and carefully picking through the detritus to find the remaining nematodes.

B. Location of variability in the Baermann funnel.

In this experiment 12 samples were handled and processed like

those in the above experiment. After 24 hours three consecutive 4 cc. samples were drawn from the Baermann funnel. The remaining contents of the funnels, approximately 500 cc., were drained into a large beaker. The funnel was again filled to the original level with tepid water. After an additional 48 hours, making a total of 72 hours of extraction, the contents of the funnels were drained into large beakers. The nematodes in the beakers were concentrated for examination by allowing the nematodes to settle to the bottom by gravity, and siphoning off the excess water with a slow acting siphon. The numbers and percentages of sting nematodes, miscellaneous nematodes, and total nematode numbers contained in the samples taken from the various levels of the Baermann funnel were determined. The coefficients of variability were calculated for nematode means for the first 4 cc. samples, funnel contents after 24 hours, and funnel contents after 72 hours.

C. Comparison of a six-inch pan method and the Baermann funnel for extracting soil nematodes.

The rolling, decanting, and washing steps were similar to those described in the two preceding sub-experiments. Eleven Baermann funnels and 11 six-inch porcelain, flat bottom pans were set up. The coefficients of variability were determined for the mean number of sting and evil nematodes from a single 4 cc. drawing after 24 hours, for the remaining contents of the Baermann funnel, and for the contents of the pan.

The pan was fitted with a piece of ½-inch hardware cloth that rested on the bottom of the pan. A circular piece of muslin was placed on top of the hardware cloth. The muslin should be of sufficient size

to extend up the side of the pan about one inch when in position. Tepid water was poured into the pan until it covered the flat muslin surface. If air bubbles should from under the muslin, they should be released by tilting the pan. At this point, the contents of the retaining sieve were gently washed into the muslin container or sack. After the desired extraction period, the muslin and its contents were gently lifted from the pan by the free edge and allowed to drain into the pan. The contents of the pan were washed into a beaker, and the nematodes were concentrated by siphoning off the excess water, which normally does not exceed 100 cc. To prevent oxidation of the hardware cloth, it was painted with black enamel paint.

D. Determination of the number of times a soil must be roiled to extract the largest number of nematodes.

The 150 cc. soil samples were roiled, decanted onto the sieves, and washed like those of the preceeding sub-experiments, except that after each decanting and washing process the contents of the 100 mesh sieve were washed into separate Baermann funnels. This process was repeated four times for each soil sample. Five 150 cc. soil samples were treated in this manner, making a total of 20 funnels. After 24 hours the contents of the funnels were drained into large beakers. Following the concentration of the nematodes by siphoning off the excess water, the numbers of sting, ring, and miscellaneous soil nematodes recovered after one to four washings were determined.

Results and Discussion

A. Variability of the Baermann funnel

The customary procedure in using the Baermann funnel to determine nematode numbers in a given sample is to draw off several cubic centimeters of water from the bottom of the funnel. For most workers this amount will probably be about 4 cc., which will cover the bottom of a 2-5/8 inches Syracuse watch glass, but will not be enough water to reduce appreciably the resolution of the nematodes under a stereoscopic microscope. Examination of the data in table 13 shows that the variability of nematode numbers from single 4 cc. samples was high, ranging from 28.2 to 40.9 percent. This variability is sufficiently high to cause lack of significance in many experiments unless there are numerous replications. The coefficient of variability was reduced after 48 and 72 hours to a level at which quantitative studies can conceivably be carried out (table 13). After standing for 48 to 72 hours, many plant parasitic nematodes fail to retain the internal definition required for finer taxonomic purposes; therefore it would be desirable to have the smallest variability possible after 24 hours, or less. This would also greatly facilitate the number of samples that could be handled in a day.

Based on the total number of nematodes recovered after 72 hours, only about 60 percent were recovered after 24 hours and 90 percent after 48 hours (table 14). The percentage of soil nematodes recovered after 24 hours and 48 hours is considerably larger than the percentage of sting nematodes and miscellaneous soil nematodes. This is not surprising because the soil nematode frequents water habitats and moist soils. In

TABLE 13

VARIABILITY OF THE BAERMANN FUNNEL AT TWENTY-FOUR HOUR INTERVALS[1]

Nematodes	Time Interval					
	24 hrs.		48 hrs.		72 hrs.	
	Mean	C.V.(%)	Mean	C.V.(%)	Mean	C.V.(%)
Sting	59.5	35.2	88.4	24.1	100.8	15.8
Awl	3.1	40.9	3.9	44.8	3.9	44.8
Miscellaneous	233.4	32.3	446.9	17.3	478.3	17.6
Total	308.4	28.2	542.9	14.4	582.9	15.2

[1]The mean and the coefficient of variability are determined on the 1st 4 cm. draining from 16 funnels.

TABLE 14

PERCENTAGE OF NEMATODES RECOVERED FROM THE BAERMANN FUNNEL AT TWENTY-FOUR HOUR INTERVALS BASED ON TOTAL NUMBER RECOVERED AFTER SEVENTY-TWO HOURS[1]

Nematodes	Time Interval	
	24 hrs.	48 hrs.
Ring	59.0	88.0
Awl	79.5	100.0
Miscellaneous	46.8	93.4
Total	52.9	93.1

[1]Percentages derived from mean of 16 funnels in table 13

an aquatic environment, such as the Baermann funnel, it would be capable of migrating through the muslin before drowning can occur, or before it becomes sluggish.

the Baermann funnel is rather efficient in extracting most nematodes. the average number of sting nematodes and miscellaneous nematodes found in the muslin sack after 72 hours was 3.3 and 3.0 respectively. No eel nematodes were found. In terms of percentages, 97 percent of the sting nematodes, 99.3 percent of the miscellaneous soil nematodes, and 100 percent of the eel nematodes placed in the funnel migrated through the muslin and were recovered after 72 hours.

B. Location of variability in the Baermann funnel.

Inasmuch as practically all nematodes migrate through the muslin sack by 72 hours, it becomes necessary to look elsewhere for the source of the observed variation. Examination of the data in table 15 shows that the first 4 cc. increment drawn from the Baermann funnel contained 69 percent of the sting nematodes and 42.9 percent of the miscellaneous nematodes present in the funnel after 24 hours. The second and third 4 cc. increments contained smaller percentages. the remaining water represents the water contained in the funnel proper. This final volume of water yielded 15.3 percent sting nematodes and 42.0 percent miscellaneous nematodes. These percentages indicate that a large number of nematodes remained in the top part of the funnel after 24 hours. On occasions, the number of nematodes retained in the top of the funnel was much larger than the number recovered in the first 4 cc. sample. Herein lies the source of the observed variation of the Baermann funnel. Data on the

TABLE 15

NUMBER AND PERCENTAGE OF NEMATODES RECOVERED FROM CONSECUTIVE SAMPLES FROM THE BAERMANN FUNNEL AFTER TWENTY-FOUR HOURS[1]

Nematodes	Consecutive samples	Average Number	Percentage
Sting			
	1st. 4cc.	63.1	69.0
	2nd. 4cc.	11.1	12.1
	3rd. 4cc.	3.2	3.5
	remainder	14.0	15.3
Miscellaneous			
	1st. 4cc.	122.4	48.9
	2nd. 4cc.	41.8	14.6
	3rd. 4cc.	1.4	0.5
	remainder	119.8	42.0
Total			
	1st. 4cc.	175.3	47.9
	2nd. 4cc.	52.8	14.4
	3rd. 4cc.	4.5	1.2
	remainder	133.0	36.4

[1]These averages are based on nematode counts from 12 funnels.

coefficients of variability for 24 hours and 72 hours also indicate this (table 16). The variability after 24 hours for the first 4 cc. draining was 55.6 percent for sting nematodes and 45.9 percent for miscellaneous nematodes, while the variability for the entire funnel contents was 16.8 percent for sting nematodes and 17.9 percent for miscellaneous soil nematodes. The variability was only slightly reduced after 72 hours.

For routine survey work, nematode examinations made on single 4 cc. drawings from the Baermann funnel will be sufficient. The Baermann funnel, as commonly used, is probably not sufficiently precise for quantitative studies unless 48 to 72 hours are allowed for extraction. Adequate quantitative results can be obtained by removing the entire water content of the funnel after 24 hours and concentrating the nematodes for subsequent examination by some suitable method. Fuller and Feldmesser (27) realized that the variability of the Baermann funnel could be reduced by examining nematodes taken from the water content of the entire funnel. They concentrated the nematodes by using suction on a Buchner funnel equipped with a fritted glass wafer. Nematodes may also be concentrated by siphoning off excess water after the nematodes have settled to the bottom of a tall column of water. More recently the author has used small metal sieves, 300 to 400 mesh and two inches in diameter, for concentrating nematodes. The contents of the Baermann funnel are allowed to drain directly into the sieve. The nematodes can then be washed into a Syracuse watch glass by using a wash bottle with a fine stream. It is important that this sieve be of considerably finer mesh than the original retaining sieve, which is usually 100 or 200 mesh; otherwise many nematodes will be lost in the final step.

TABLE 16

COMPARISON OF COEFFICIENTS OF VARIABILITY FOR NEMATODE NUMBERS FROM CUSTOMARY SAMPLE SIZE AND CONTENTS OF THE BAERMANN FUNNEL[1]

Nematodes	Time Interval			
	24 hrs.		72 hrs.	
	1st. 4oz. drawing C. V. (%)	Funnel contents C. V. (%)		Funnel contents C.V. (%)
Sting	35.6	16.8		15.4
Miscellaneous	43.9	17.9		14.3
Total	48.9	14.8		11.9

[1]The coefficients of variability are based on 12 funnels.

C. Comparison of a six-inch pan method and the Baermann funnel for extracting soil nematodes.

As in the other cases, the first 4 cc. drawing from the Baermann funnel had a high coefficient of variability for sting nematodes (table 17). Even though the 11 Baermann funnels and 11 pans were set up from the same soil mixture and handled alike in every respect, the coefficients of variability for container contents were considerably lower for the pan method than for the Baermann funnel. The lower variability of the pan method is probably due to two factors: one, the flat muslin surface allows quicker migration of the nematodes because the detritus is spread out over a larger area than is possible in the muslin sack of the Baermann funnel, and secondly, due to the increased surface, better oxygenation of the sample allows longer survival of the nematodes.

On the basis of the findings from the pan method, a new type of muslin container was devised for the Baermann funnel. It has been used successfully for some time in routine determinations, though its variability has not yet been determined. The muslin sack with its supporting wire hoop is replaced by a piece of muslin fixed tightly in position by a wide rubber band on a two-inch section of four-inch extruded aluminum irrigation pipe. The older type muslin sack is hard to clean and sterilize, and requires considerable work in making new sacks when the old sacks deteriorate. These difficulties are overcome with the present muslin bottom aluminum ring. For precise results it will still be necessary to make counts on the entire water content of the funnel.

The Baermann funnel equipped with the muslin bottom aluminum ring is, to date, the best means of extracting soil nematodes. No other method

TABLE 17

VARIABILITY[1] OF THE BAERMANN FUNNEL AND PAN METHODS IN EXTRACTING SOIL NEMATODES

Method	Nematodes			
	Sting		Awl	
	1st. 4cc. drawing C.V. (%)	container contents C.V. (%)	1st. 4cc. drawing C.V. (%)	container contents C.V. (%)
Baermann funnel	43.8	25.7	48.1	24.2
Six-inch pan	-	16.5	-	14.4

[1] The coefficients of variability are determined from 11 pans and 11 funnels.

has been found superior for routine laboratory work, and it may be adapted to quantitative as well as qualitative nematode counts. The pan method has some advantages for certain types of work. In field survey problems, transporting and setting up of the Baermann funnels and funnel racks often becomes a problem. The pan method may alleviate some of these difficulties.

D. Determination of the number of times a soil sample must be rolled to extract the largest number of nematodes.

No doubt some nematodes are lost in the gravity-sieving process because they will pass through the fine sieve, particularly small species and larval forms. For this reason nematode counts do and necessarily represent the actual number of nematodes in the soil. For a specified retaining sieve, nematode counts based on the Baermann funnel give reliable indices of nematode infestations. In this study, the percentage of nematodes extracted refers to the number actually retained and recovered from the Baermann funnel.

Counts made on sting, ring, and miscellaneous soil nematodes from sandy soil showed that 80 to 85 percent were removed from the soil after the first rolling and decanting process (table 18). After four such processings 99 to 100 percent of the soil nematodes were removed. For most experimental nematode determinations three or four repetitions of the rolling and decanting process should be sufficient. For routine qualitative studies two such repetitions should suffice. These suggestions will apply only to sandy soils. It is likely that the same suggestions can be made for loam soils, and possibly heavier soils.

TABLE 18

NUMBER AND PERCENTAGE OF NEMATODES EXTRACTED FROM THE SOIL AFTER SOAKING AND DECANTING ONE TO FOUR TIMES[1]

Nematodes	Washings							
	1		2		3		4	
	No.	%	No.	%	No.	%	No.	%
Sting	46.8	79.9	9.8	17.0	1.8	3.1	0.0	0.0
Ring	14.0	79.8	3.4	19.1	0.0	0.0	0.8	1.1
Miscellaneous	107.4	86.9	14.2	11.5	1.6	1.3	0.4	0.3
Total	167.8	84.8	27.4	13.8	3.4	1.7	0.6	0.3

[1]The number and percentage of nematodes extracted at each washing is based on an average of 5 funnels.

In the case of organic soils, samples must be processed differently. If a 150 cc. soil sample is used, three or four rolling and decanting steps must be used. The material caught on the retaining sieve after each processing must be washed into separate funnels because of the volume of organic matter that is carried over into the funnel. Experience has shown that when too much organic material, such as that obtained from peat soils, is carried over into the funnel the number of nematodes extracted is reduced.

GENERAL DISCUSSION AND SUMMARY

In a crop rotation study from 1952 to 1955 at Quincy, Florida, the numbers of plant parasitic, predaceous, and saprophagous nematodes were determined for continuous cropping practices and two- and three-year crop rotations involving Dixie Runner peanuts, Dixie 18 corn, native cover, bitter blue lupine, and Southland oats.

Significantly higher numbers of smooth-headed meadow nematodes, Pratylenchus leiocephalus, were present in the soil following corn than were found after peanuts. The largest populations occurred when corn was grown continuously. However, when corn was grown in rotation with peanuts the numbers decreased. The lowest infestation following corn occurred in the two-year rotation with intermediate numbers occurring where corn, the most susceptible plant, was grown two years and peanuts one. Other plant parasites were present in smaller numbers. Populations of lance nematodes, Hoplolaimus coronatus, stubby-root nematodes, Trichodorus spp., and dagger nematodes, Xiphinema americanum, behaved similarly to meadow nematodes with respect to corn and peanuts. On the other hand Criconemoides spp. populations were larger following peanuts than corn. Large numbers of ring nematodes, Criconemoides spp., were associated with reduced yeu and yield. Lupine and oats appeared to support larger numbers of meadow and ring nematodes than native cover. In continuous corn plots, the numbers of lance and dagger nematodes were significantly higher when native cover was present than when lupine was present. Saprophagous soil nematodes were associated with a high percentage of soil organic matter, the largest numbers occurring in the long rotations. Predaceous

nematodes of the genus Mesocriconema correlated with the largest group of soil nematodes, the saprophagous forms. The bulk of the nematodes belonging to the superfamily Dorylaimoidea, exclusive of Xiphinema and Trichodorus, probably feed to some extent on plants because their numbers correlated with crops rather than with soil organic matter and saprophagous nematodes. Similar observations were obtained from related rotations at Marianna and Jay, Florida.

On the basis of these findings and those of Graham (40) and Sasser (74), it is evident that meadow nematode populations are reduced where peanuts are grown, and are increased where corn is grown. The data reported here indicate that peanuts may be used in a rotation to reduce populations of meadow, lance, dagger, and stubby-root nematodes. In pot studies Graham (41) found that peanuts reduced sting nematode populations; therefore, it is probable that peanuts grown in rotation with corn and other susceptible crops will aid in reducing the number of these nematodes in the soil. As has been shown in this experiment, as well as by Machmer (56, 57), peanuts have a tendency to increase the numbers of sting nematodes, particularly where continuous peanuts are grown.

In greenhouse pot studies, six winter legumes and Aristogold sweet corn were inoculated with 50 handpicked specimens of Belonolaimus gracilis. After 10 weeks the build up of sting nematodes on the various plants was determined. Vetch, sweet corn, and Dixie crimson clover had significantly larger numbers of sting nematodes than bitter blue lupine. Of the legumes, vetch and Dixie crimson clover favor the development of sting nematodes more than bitter blue lupine, Rhoan, Austrian winter pea,

and sweet yellow lupine. Sweet corn was included in this experiment as a reference plant to be used in making comparisons of plants grown at different times under different conditions.

Of the six legumes tested, bitter blue lupine will probably be a good winter cover crop for controlling sting nematodes. Crotalaria probably is superior in this respect as a summer cover crop, for Holdeman and Graham (46) found that sting nematode populations were reduced by this plant.

The influence of soil fertility on plant parasitic nematode populations was tested in field plot studies at Sanford, Florida. Treatments consisted of no fertilizer and low, medium, and high fertility levels. For sweet corn these respective treatments were 0, 1000, 2000, and 3000 pounds per acre of a 4-5-7 fertilizer, and for celery no fertilizer and one, three, and five tons per acre of 5-5-8 fertilizer. Though significantly more corn ears were harvested from the highest fertility level, there was no significant increase in the total ear weight above 1000 pounds per acre of fertilizer. Populations of awl and stubby-root nematodes increased with fertility. It is assumed that the nematode populations were a limiting factor in corn production in this experiment because of the correlations of plant parasitic nematodes with fertility and lack of increase in total weight of ears harvested from fertility levels above 1000 pounds per acre of fertilizer.

For celery, yields increased with fertility through the one- and three-ton fertilizer rates, and decreased at the five-ton rate. The nematode populations of the ten parasites increased over the four fertility levels at the mid-point of the celery growing season; however,

by harvest time the populations increased from the check to the one-ton fertilization rate and decreased from the three- to five-ton application rates. This suggests that the populations build up at the high fertility levels during the period that the plants were able to put out new roots, and decreased as maturity approached because of lack of new root growth. Root weights followed the nematode parasite populations at harvest time. The root weights increased from the check to the one-ton fertilization rate, at which point there was a sharp reduction in root weight. Inasmuch as the celery yields increased through the three-ton rate, additions of fertilizer at this rate apparently allowed increases in celery yield despite high nematode populations and restricted root development. The decline of celery yield at the five-ton fertilizer rate is probably due to some cause other than nematodes. It may be speculated that high salt concentration or nutrient unbalance are contributing influences.

In a series of experiments, sources of experimental error were determined for the commonly used Christie-Perry method (19) of extracting soil nematodes. Nematode counts are generally made on approximately 4 cc. of water drawn from the bottom of the Baermann funnel. It was found that the coefficient of variability after 24 hours for such samples was high, usually between 30 and 55 percent. By allowing the extraction of nematodes to proceed for 72 hours this variability was reduced to approximately 15 percent. By draining the entire water content from the funnel after 24 hours and concentrating the nematodes for examination, the coefficient of variability can be reduced to 15 percent or less. When species determinations are required for plant parasitic nematodes, they must not stand in water any longer than absolutely necessary. Therefore, it is

desirable to recover them after 24 hours with as little experimental error as possible.

The variability of the Baermann funnel was located by examining successive increments of water drawn from the funnel. Large variations in the number of nematodes in the first 4 cc. sample occurred. In certain instances only a few nematodes were found in the first drawing, while large numbers were found in the top part of the funnel. On a percentage basis, the first 4 cc. drawing contained 48 percent of the total number of nematodes in the funnel. The second and third 4 cc. drawings and the water remaining in the top part of the funnel contained respectively 14, 1, and 36 percent of the total number of nematodes.

The Baermann funnel is very efficient in extracting most soil nematodes that are placed in the muslin sack. Ninety-seven percent of the sting nematodes, 99 percent of the miscellaneous soil nematodes, and 100 percent of the soil nematodes placed in the muslin sack of the Baermann funnel migrated through the muslin and were recovered after 72 hours.

A six-inch porcelain, flat bottom pan with a piece of muslin held slightly above the pan bottom by a section of hardware cloth was substituted for the Baermann funnel. Nematode counts based on this extraction apparatus showed less variability than those from the Baermann funnel. This type of extracting unit may possibly be of use in field studies where portable laboratory equipment is desired.

On the basis of experimental studies, the Christie-Perry method may be used in quantitative experimental work. Best results are obtained by making determinations on the entire water content of the funnel. Foster and Fahnestock (28) used a Buchner funnel to concentrate the

nematodes contained in the water from the funnel. A simpler method, which has been used with satisfactory results, is to allow the contents of the Baermann funnel to drain into a small 300 or 400 mesh sieve. The nematodes can then be washed with a small amount of water into an examining dish.

CONCLUSIONS

1. The effect of certain crop rotations on nematode populations.

Dixie 18 corn supported larger numbers of Pratylenchus leiocephalus than Dixie Runner peanuts. Continuous corn had the largest populations, and corn grown in a two-year rotation with peanuts had smaller populations. Three-year rotations in which corn was grown two years and peanuts one had rather large populations, but not as large as those from continuous corn. Populations of Hoplolaimus coronatus, Trichodorus spp., and Xiphinema americanum behaved similarly to Pratylenchus leiocephalus with respect to corn and peanut rotations. In contrast to the other plant parasites, Criconemoides spp. appeared in largest numbers where peanuts were grown. Saprophagous soil nematodes were associated with a high percentage of soil organic matter. They were the largest group present in soil. The predaceous Mesonchus spp. were associated with this group. Populations of Dorylaimoides, exclusive of Xiphinema and Trichodorus, showed population trends similar to those of plant parasites. Winter cover crops did not influence the populations to any great extent; however, bitter blue lupine and Southland oats appeared to support larger populations of Pratylenchus leiocephalus and Criconemoides spp. than native cover. Native cover supported larger populations of Hoplolaimus coronatus and Xiphinema americanum than bitter blue lupine.

High population peaks occurred in July for Criconemoides spp., Trichodorus spp. and Dorylaimoides. Lower populations occurred in the winter. Populations of Pratylenchus leiocephalus were low during the winter, increased during the spring and summer, and reached a high peak in October.

2. The relative build up of sting nematodes on selected cover crops.

Ten weeks after inoculation with 50 specimens of Belonolaimus gracilis it was found that numbers of these organisms had increased significantly on vetch and Dixie crimson clover, while bitter blue lupine barely maintained the original population. Significant differences did not occur for Ribon, sweet yellow lupine, and Austrian winter peas; although populations tended to be small on Ribon and sweet yellow lupine, and slightly larger on Austrian winter peas.

3. Effects of soil fertility levels on plant parasitic nematode populations.

During the corn growing season, populations of Heliocotylenchus heterocephalus and Trichodorus spp. increased with fertility. The parasitic nematodes apparently become a limiting factor in corn yield.

During the celery growing season, the same parasites increased as the fertility increased through the mid-point of the growing season, but decreased by harvest time in the medium and high fertility levels. Plant parasitic nematode populations increased rapidly under high fertility practices. Additions of fertilizer through the medium fertility level allowed increased celery yields despite high nematode populations and restricted root development.

4. Evaluation of the Christie-Perry method of extracting soil nematodes.

The coefficient of variability for a single 4 cc. sample drawn from the Baermann funnel after 24 hours was too large for most experimental work. The variability was reduced after 72 hours to about

15 percent. By draining the funnel and concentrating the nematodes after 24 hours, the coefficient of variability was reduced to about 15 percent. Variability in the Baermann funnel resulted from disproportionate numbers of nematodes settling to the bottom of the funnel. A large percentage often remained in the top part of the funnel. These were not recovered unless the funnel was drained. Ninety-seven to 100 percent of the nematodes initially placed in the funnel were recovered after 72 hours.

For sandy soils, four rolling and decanting processes removed 99 to 100 percent of the nematodes carried over into the Baermann funnel.

A six-inch porcelain, flat bottom pan, which embodied the same principle as the Baermann funnel, was more precise than the Baermann funnel in extracting soil nematodes.

APPENDIX

TABLE I

EFFECT OF CROP ROTATIONS ON FRATYLENCHUS LESIONANUS NUMBERS
QUINCY, FLORIDA
October 30, 1953

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	7	5	1	4	4.2
Peanuts (lupine)	7	10	15	28	15.0
Corn (native)	110	162	146	76	123.5
Corn (lupine)	237	445	402	189	323.3
Two-year rotation					
Peanuts (lupine)	17	12	14	10	13.5
Corn (native)	62	69	81	92	76.0
Three-year rotation					
Peanuts (lupine)	6	9	10	6	7.8
Corn (lupine)	169	247	341	319	269.0
Corn (oats)	216	220	130	63	157.3

TABLE II

EFFECT OF CROP ROTATIONS ON FRACTIONOUS LEUCOPHYLLUM BURNING QUINCY, FLORIDA
February 6, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	1	4	4	2.7
Peanuts (lupine)	1	2	7	3.3
Corn (native)	54	17	285	98.7
Corn (lupine)	42	117	25	61.3
Two-year rotation				
Peanuts (lupine)	7	2	6	5.0
Corn (native)	23	16	46	28.4
Three-year rotation				
Peanuts (lupine)	2	4	2	2.7
Corn (lupine)	27	139	163	109.8
Corn (ente)	37	153	80	80.0

TABLE XIX

EFFECT OF CROP ROTATIONS ON *PRATYLENCHUS* *LESIONPHALUS* NUMBERS
QUINCY, FLORIDA
July 23, 1954

Cropping System	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	2	3	1	2.0
Peanuts (lupine)	3	3	11	5.7
Corn (native)	193	302	299	264.7
Corn (lupine)	675	315	219	403.0
Two-year rotation				
Peanuts (lupine)	3	8	13	8.0
Corn (native)	16	13	18	15.7
Three-year rotation				
Peanuts (lupine)	6	45	17	22.7
Corn (lupine)	26	39	64	43.0
Corn (oats)	85	322	119	175.3

TABLE IV

EFFECT ON CROP ROTATIONS ON *PRATYLENCHUS* *LEIOCEPHALUS* NUMBERS
QUincy, Florida
January 14, 1955

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	2	0	0	0	0.5
Peanuts (lupine)	2	0	0	0	0.5
Corn (native)	40	18	25	50	31.8
Corn (lupine)	42	21	49	60	42.8
Two-year rotation					
Peanuts (lupine)	4	1	1	1	1.8
Corn (native)	1	2	5	1	2.3
Three-year rotation					
Peanuts (lupine)	6	3	1	0	2.3
Corn (lupine)	7	15	12	18	10.2
Corn (oats)	10	25	26	15	18.5

TABLE V

EFFECT OF CROP ROTATION ON CHICORIUM SPP. NUMBERS
QUINCY, FLORIDA
October 30, 1953

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	0	0	0	0	1.0
Peanuts (lupine)	0	1	0	1	0.5
Corn (native)	4	1	0	0	1.3
Corn (lupine)	0	7	0	0	2.3
Two-year rotation					
Peanuts (lupine)	7	1	0	0	2.0
Corn (native)	0	0	1	1	0.5
Three-year rotation					
Peanuts (lupine)	16	9	1	4	7.5
Corn (lupine)	1	1	0	0	0.5
Corn (oats)	0	1	0	0	0.3

TABLE VI

EFFECT OF CROP ROTATIONS ON CRICONEMOIDES SPP. NEMATODES
QUINCY, FLORIDA
February 6, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	0	1	1	0.7
Peanuts (lupine)	0	0	1	0.3
Corn (native)	1	0	1	0.7
Corn (lupine)	0	3	0	1.0
Two-year rotation				
Peanuts (lupine)	0	0	4	1.3
Corn (native)	0	0	0	0.0
Three-year rotation				
Peanuts (lupine)	1	6	1	0.7
Corn (lupine)	0	0	1	0.3
Corn (oats)	0	1	0	0.3

TABLE VII

EFFECT OF CROP ROTATION ON *CHLOROTHROLUM* SPP. POPULATIONS
QUincy, FLORIDA
July 23, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	90	37	84	50.3
Peanuts (lupine)	82	34	113	56.4
Corn (native)	15	2	10	9.0
Corn (lupine)	10	15	8	11.0
Two-year rotation				
Peanuts (lupine)	7	6	3	5.3
Corn (native)	14	9	8	10.3
Three-year rotation				
Peanuts (lupine)	10	3	20	11.0
Corn (lupine)	10	7	6	7.7
Corn (oats)	3	1	1	1.7

TABLE VIII

EFFECT OF CROP ROTATIONS ON *CRICONEMOIDES* SPP. NUMBERS
QUINCY, FLORIDA
January 14, 1955

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	33	3	13	16	16.3
Peanuts (lupine)	9	14	28	13	16.0
Corn (native)	7	3	6	2	4.0
Corn (lupine)	4	2	3	8	4.3
Two-year rotation					
Peanuts (lupine)	11	7	15	9	10.5
Corn (native)	12	14	8	2	9.0
Three-year rotation					
Peanuts (lupine)	1	3	13	5	5.5
Corn (lupine)	3	3	3	3	3.0
Corn (oats)	4	1	0	1	1.5

TABLE IX

EFFECT OF CROP ROTATIONS ON *RHIZOCTONIA SOLANI* NUMBERS
QUINCY, FLORIDA
October 30, 1953

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	0	1	0	0	0.3
Peanuts (lupine)	0	0	2	1	1.3
Corn (native)	9	4	11	44	17.0
Corn (lupine)	8	5	15	60	22.0
Two-year rotation					
Peanuts (lupine)	0	0	0	2	0.5
Corn (native)	0	2	4	4	2.5
Three-year rotation					
Peanuts (lupine)	0	0	3	0	0.8
Corn (lupine)	0	2	1	1	1.0
Corn (oats)	0	1	3	3	1.6

TABLE X

EFFECT OF CROP ROTATIONS ON NEMATODE CONTROL DURING QUINCY, FLORIDA February 6, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	0	0	1	0.3
Peanuts (lupine)	0	0	0	0.0
Corn (native)	7	1	16	8.0
Corn (lupine)	6	3	8	5.7
Two-year rotation				
Peanuts (lupine)	0	0	0	0.0
Corn (native)	0	0	0	0.7
Three-year rotation				
Peanuts (lupine)	0	1	0	0.3
Corn (lupine)	0	1	1	0.7
Corn (oats)	0	1	1	0.7

TABLE XI

EFFECT OF CROP ROTATIONS ON [illegible] CONIDIUM NUMBERS
QUINCY, FLORIDA
July 23, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	6	0	0	0.0
Peanuts (lupine)	1	0	0	0.3
Corn (native)	30	8	3	13.7
Corn (lupine)	8	1	18	9.0
Two-year rotation				
Peanuts (lupine)	1	0	0	0.3
Corn (native)	0	0	0	0.0
Three-year rotation				
Peanuts (lupine)	2	0	0	0.7
Corn (lupine)	0	0	8	0.7
Corn (oats)	3	0	1	1.3

TABLE XII

EFFECT OF CROP ROTATIONS ON EXPLOSIVE CORCHORUS NUMBERS
QUINCY, FLORIDA
January 14, 1955

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts(native)	1	0	0	0	0.3
Peanuts (lupine)	0	0	0	0	0.0
Corn (native)	6	3	14	12	8.8
Corn (lupine)	0	0	1	8	2.8
Two-year rotation					
Peanuts (lupine)	0	1	0	1	0.5
Corn (native)	0	0	0	0	0.0
Three-year rotation					
Peanuts (lupine)	0	0	0	0	0.0
Corn (lupine)	0	1	0	0	0.3
Corn (oats)	0	0	0	0	0.0

TABLE XIII

EFFECT OF CROP ROTATIONS ON TYLENCHORHYNCHUS SPP. NEMATODES
QUINCY, FLORIDA
February 6, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	0	0	0	0.0
Peanuts (lupine)	0	0	0	0.0
Corn (native)	0	0	0	0.7
Corn (lupine)	0	0	1	0.3
Two-year rotation				
Peanuts (lupine)	0	0	0	0.0
Corn (native)	1	1	1	1.0
Three-year rotation				
Peanuts (lupine)	0	0	0	0.0
Corn (lupine)	3	4	5	4.0
Corn (oats)	0	0	0	0.0

TABLE XIV

EFFECT OF CROP ROTATIONS ON *TYLENCHORHYNCHUS* SPP. NUMBERS
QUINCY, FLORIDA
July 23, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	0	0	0	0.0
Peanuts (lupine)	0	0	0	0.0
Corn (lupine)	11	27	127	55.0
Corn (native)	27	22	66	30.0
Two-year rotation				
Peanuts (lupine)	9	5	6	6.7
Corn (native)	16	3	4	7.7
Three-year rotation				
Peanuts (lupine)	6	4	11	7.0
Corn (lupine)	9	17	33	19.7
Corn (oats)	92	80	52	60.7

TABLE XV

EFFECT OF CROP ROTATIONS ON THICKNESS OF ROOTS
QUincy, Florida
January 14, 1955

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	0	0	0	0	0.0
Peanuts (lupine)	0	0	0	0	0.0
Corn (native)	18	10	8	10	11.5
Corn (lupine)	14	11	6	3	8.5
Two-year rotation					
Peanuts (lupine)	2	0	0	1	1.3
Corn (native)	0	1	1	1	0.8
Three-year rotation					
Peanuts (lupine)	3	1	0	3	1.8
Corn (lupine)	5	10	5	1	5.3
Corn (oats)	9	1	7	3	5.0

TABLE XVI

EFFECT OF CROP ROTATIONS ON *HYPERICUM AMERICANUM* NEMATODE
QUINCY, FLORIDA
February 6, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	0	1	0	0.3
Peanuts (lupine)	0	0	0	0.0
Corn (native)	37	0	0	12.3
Corn (lupine)	5	0	0	2.3
Two-year rotation				
Peanuts (lupine)	0	0	0	0.0
Corn (native)	5	0	0	1.7
Three-year rotation				
Peanuts (lupine)	0	0	0	0.0
Corn (lupine)	8	0	0	2.7
Corn (oats)	7	0	0	2.3

TABLE XVII

EFFECT OF CROP ROTATIONS ON *HETERODERA MARIONI* NEMATODE
QUINCY, FLORIDA
July 23, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	1	3	0	1.3
Peanuts (lupine)	1	0	1	0.7
Corn (native)	60	3	4	22.3
Corn (lupine)	6	0	6	4.0
Two-year rotation				
Peanuts (lupine)	0	0	2	0.7
Corn (native)	0	0	0	0.0
Three-year rotation				
Peanuts (lupine)	0	2	0	0.7
Corn (lupine)	2	0	1	1.0
Corn (oats)	23	1	1	7.3

TABLE XVIII

EFFECT OF CROP ROTATIONS ON *RHIZOBIUM AMERICANUM* NUMBERS
QUINCY, FLORIDA
January 14, 1955

Cropping System	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	0	0	0	0	0.5
Peanuts (lupine)	0	0	1	0	0.3
Corn (native)	147	0	0	0	36.8
Corn (lupine)	17	0	0	0	4.3
Two-year rotation					
Peanuts (lupine)	11	0	0	0	2.8
Corn (native)	15	0	0	0	4.8
Three-year rotation					
Peanuts (lupine)	1	0	0	0	0.3
Corn (lupine)	0	0	0	0	0.0
Corn (oats)	38	0	0	0	9.5

TABLE XIX

EFFECT OF CROP ROTATIONS OF NEMATODES EFF. NUMBERS
QUINCY, FLORIDA
October 30, 1953

Cropping System	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	0	0	1	1	0.5
Peanuts (lupine)	0	0	0	1	0.3
Corn (native)	10	1	24	9	11.0
Corn (lupine)	0	1	9	11	5.0
Two-year rotation					
Peanuts (lupine)	0	1	0	0	0.3
Corn (native)	0	0	1	0	0.3
Three-year rotation					
Peanuts (lupine)	0	0	1	5	1.5
Corn (lupine)	5	7	0	5	4.0
Corn (oats)	0	7	0	4	3.3

TABLE XX

EFFECT OF CROP ROTATIONS ON MELOIDOGYNE SPP. INDICES
QUINCY, FLORIDA
February 6, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	0	0	0	0.0
Peanuts (lupine)	0	0	0	0.0
Corn (native)	8	8	35	15.0
Corn (lupine)	0	8	9	6.4
Two-year rotation				
Peanuts (lupine)	4	0	11	5.7
Corn (native)	13	2	5	6.7
Three-year rotation				
Peanuts (lupine)	3	1	4	2.7
Corn (lupine)	8	9	5	7.3
Corn (oats)	0	6	4	4.0

TABLE XXI

EFFECT OF CROP ROTATION ON NEMATODES SOY. BEANS
QUINCY, FLORIDA
July 23, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	0	1	0	0.3
Peanuts (lupine)	0	0	0	0.0
Corn (native)	2	0	0	0.7
Corn (lupine)	0	0	0	0.0
Two-year rotation				
Peanuts (lupine)	0	0	2	0.7
Corn (native)	0	0	0	0.0
Three-year rotation				
Peanuts (lupine)	0	0	0	0.0
Corn (lupine)	0	0	0	0.0
Corn (oats)	0	0	0	0.0

TABLE XXII

EFFECT OF CROP ROTATIONS ON MELOIDOGYNE SPP. NUMBERS
QUINCY, FLORIDA
January 14, 1953

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	0	0	0	0	0.0
Peanuts (lupine)	0	0	1	0	0.3
Corn (native)	2	4	1	4	2.8
Corn (lupine)	4	1	6	1	3.0
Two-year rotation					
Peanuts (lupine)	2	0	2	1	1.3
Corn (native)	0	1	0	1	0.5
Three-year rotation					
Peanuts (lupine)	0	0	0	1	0.3
Corn (lupine)	0	0	0	0	0.0
Corn (oats)	0	1	2	0	0.8

TABLE XXXII

EFFECT OF CROP ROTATIONS ON NONPARASITIC NEMATODES[1]
QUincy, FLORIDA
February 6, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	2	8	7	5.7
Peanuts (lupine)	2	7	19	9.3
Corn (native)	30	10	67	35.7
Corn (lupine)	14	18	10	14.2
Two-year rotation				
Peanuts (lupine)	2	11	10	7.7
Corn (native)	18	13	8	13.0
Three-year rotation				
Peanuts (lupine)	6	6	5	5.7
Corn (lupine)	22	20	16	19.3
Corn (oats)	15	12	13	13.3

[1]Exclusive Xiphinema and Trichodorus

TABLE XXIV

EFFECT OF CROP ROTATIONS ON POPULATIONS NUMBERS[1]
QUINCY, FLORIDA
July 23, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	26	40	19	28.3
Peanuts (lupine)	11	28	138	59.0
Corn (native)	211	93	190	164.7
Corn (lupine)	212	53	190	151.7
Two-year rotation				
Peanuts (lupine)	73	62	68	67.7
Corn (native)	72	19	48	46.3
Three-year rotation				
Peanuts (lupine)	151	85	118	118.0
Corn (lupine)	48	137	106	97.7
Corn (oats)	158	87	101	115.3

[1]Inclusive of Xiphinema and Trichodorus

TABLE XIV

EFFECT OF CROP ROTATIONS ON PUNTLANDIELLA HIRSUTE[1]
QUINCY, FLORIDA
January 24, 1955

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	25	4	9	5	10.8
Peanuts (lupine)	4	1	7	0	3.0
Corn (native)	82	85	39	37	60.8
Corn (lupine)	71	83	80	25	49.8
Two-year rotation					
Peanuts (lupine)	24	6	8	13	12.8
Corn (native)	24	18	13	8	13.3
Three-year rotation					
Peanuts (lupine)	40	29	4	3	19.0
Corn (lupine)	20	29	14	1	16.0
Corn (oats)	52	31	53	25	40.3

[1]Exclusive of Xiphinema and Trichodorus

TABLE XXVI

EFFECT OF CROP ROTATIONS ON MISCELLANEOUS BENEFICIAL MICROBES
QUINCY, FLORIDA
October 30, 1953

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	146	225	172	276	204.8
Peanuts (lupine)	73	506	280	499	324.8
Corn (native)	567	815	246	278	476.5
Corn (lupine)	551	514	1020	395	620.0
Two-year rotation					
Peanuts (lupine)	959	847	919	815	735.0
Corn (native)	636	690	964	544	691.0
Three-year rotation					
Peanuts (lupine)	280	680	314	347	430.3
Corn (lupine)	751	586	656	701	673.5
Corn (oats)	877	810	366	374	556.8

TABLE XXVII

EFFECT OF CROP ROTATIONS ON MISCELLANEOUS MINERIOUS NUTRIENTS
QUINCY, FLORIDA
February 6, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	52	77	114	81.0
Peanuts (lupine)	141	51	212	134.7
Corn (native)	303	135	1243	507.0
Corn (lupine)	352	336	827	305.0
Two-year rotation				
Peanuts (lupine)	93	89	302	161.3
Corn (native)	532	498	787	582.3
Three-year rotation				
Peanuts (lupine)	198	204	73	158.3
Corn (lupine)	763	384	823	656.7
Corn (oats)	432	355	362	383.0

TABLE XXVIII

EFFECT OF CROP ROTATIONS ON MISCELLANEOUS SUMMER NURSERY

QUINCY, FLORIDA
July 23, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous				
Peanuts (native)	103	44	47	64.7
Peanuts (lupine)	31	37	159	75.7
Corn (native)	283	185	149	205.7
Corn (lupine)	335	179	109	214.3
Two-year rotation				
Peanuts (lupine)	140	61	61	87.3
Corn (native)	107	111	76	98.0
Three-year rotation				
Peanuts (lupine)	157	81	230	156.3
Corn (lupine)	98	218	231	182.3
Corn (oats)	295	320	381	332.0

TABLE XXIX

EFFECT OF CROP ROTATIONS ON MISCELLANEOUS MEMPHIS SOILS
QUINCY, FLORIDA
January 14, 1953

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	55	32	42	44	43.3
Peanuts (lupine)	14	39	86	47	31.5
Corn (native)	139	102	184	213	144.5
Corn (lupine)	191	149	134	215	172.3
Two-year rotation					
Peanuts (lupine)	126	53	91	59	82.8
Corn (native)	59	51	91	134	83.8
Three-year rotation					
Peanuts (lupine)	146	66	34	61	76.8
Corn (lupine)	79	186	136	194	148.8
Corn (oats)	127	74	253	64	129.3

TABLE XIX

EFFECT OF CROP ROTATIONS ON TOTAL NEMATODE NUMBERS
QUINCY, FLORIDA
April 30, 1952

Cropping Systems	Plot No.	Replications				Av.
		1	2	3	4	
Continuous:						
Peanuts (native)[1] *	1	47	49	41	56	48
Peanuts (lupine)*	2	184	186	72	382	162
Corn (sorg., oats)	3	196	205	705	378	346
Corn (crotalaria)	4	338	184	488	567	345
Corn (lupine)*	5	162	453	651	850	354
Corn (native)*	6	180	188	451	472	333
Two-year rotations						
Peanuts (lupine)*	7	110	113	409	285	229
Corn (native)*	10	198	89	203	121	153
Peanuts (lupine)	8	123	91	420	303	234
Corn (velvet beans)	11	206	384	612	231	359
Peanuts (lupine)	9	190	103	336	369	241
Corn (crotalaria)	12	240	309	419	367	336
Three-year rotations						
Peanuts (lupine)*	13	109	207	418	234	242
Corn (lupine)*	15	197	403	163	360	281
Corn (oats)*	17	384	179	498	458	380
Peanuts (lupine)	14	68	116	396	275	214
Corn, oats	16	334	284	506	346	368
(Crotalaria, oats)	18	215	178	461	314	292
				L.S.D. .05		138
				L.S.D. .01		212

[1]Rotations marked by an asterisk were used in all studies at this location.

TABLE XXXI

EFFECT OF CROP ROTATIONS ON TOTAL SEASONAL HERBAGE
QUINCY, FLORIDA
January 7, 1953

Cropping Systems	Plot No.	Replications				Av.
		1	2	3	4	
Continuous:						
Peanuts (native)*	1	45	24	54	24	37
Peanuts (lupine)*	2	53	46	54	49	50
Corn (sweet, oats)	3	360	221	512	398	363
Corn (crotalaria)	4	321	301	232	430	321
Corn (lupine)*	5	502	633	638	480	502
Corn (native)*	6	568	494	859	351	568
Two-year rotations						
Peanuts (lupine)*	7	66	112	145	88	103
Corn (native)*	10	114	66	217	186	146
Peanuts (lupine)	8	79	145	212	100	134
Corn (velvet beans)	11	110	184	117	202	153
Peanuts (lupine)	9	122	94	222	197	159
Corn (crotalaria)	12	127	146	156	223	163
Three-year rotations						
Peanuts (lupine)*	13	228	213	282	249	243
Corn (lupine)*	15	184	198	358	381	281
Corn (oats)*	17	123	151	153	201	167
Peanuts (lupine)	14	230	113	139	155	159
Corn, oats	16	284	180	305	105	203
(Crotalaria, oats)	18	160	680	269	219	317
				L.S.D.	.05	78
				L.S.D.	.01	105

[1]Rotations marked by an asterisk were used in all studies at this location.

TABLE XXXII

EFFECT OF CROP ROTATIONS ON TOTAL NITROGEN CONTENT
QUINCY, FLORIDA
June 16, 1953

Cropping Systems	Plot No.	Replications			Av.
		1	2	3	
Continuous:					
Peanuts (native)*	1	26	30	20	25
Peanuts (lupine)*	2	25	30	20	25
Corn (crot., oats)	3	427	405	547	460
Corn (crotalaria)	4	393	100	320	271
Corn (lupine)*	5	435	166	225	275
Corn (native)*	6	223	197	42	154
Two-year rotations					
Peanuts (lupine)*	7	153	107	185	185
Corn (native)*	10	292	67	173	177
Peanuts (lupine)	8	41	75	47	54
Corn (velvet beans)	11	65	80	49	65
Peanuts (lupine)	9	48	63	58	54
Corn (crotalaria)	12	66	80	38	61
Three-year rotations					
Peanuts (lupine)*	13	273	199	51	174
Corn (lupine)*	15	107	30	52	70
Corn (oats)*	17	150	136	189	146
Peanuts (lupine)	14	225	100	49	154
Corn, oats	16	137	104	89	110
(Crotalaria, oats)	18	100	160	83	114
				L.S.D. .05	110
				L.S.D. .01	154

[1]Rotations marked by an asterisk were used in all studies at this location.

TABLE XXXIII

EFFECT OF CROP ROTATIONS ON TOTAL NEMATODE NUMBERS
QUINCY, FLORIDA
October 30, 1953

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	155	233	174	281	211
Peanuts (lupine)	80	519	237	520	339
Corn (native)	700	983	427	407	629
Corn (lupine)	796	972	1468	655	973
Two-year rotation					
Peanuts (lupine)	983	861	933	289	758
Corn (native)	700	721	1051	643	779
Three-year rotation					
Peanuts (lupine)	402	698	329	362	448
Corn (lupine)	987	843	1000	1027	949
Corn (oats)	1093	839	401	444	694

TABLE XXXIV

EFFECT OF CROP ROTATIONS ON TOTAL NEMATODE NUMBERS
QUINCY, FLORIDA
February 6, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	54	91	127	91
Peanuts (lupine)	144	60	239	148
Corn (native)	520	163	1419	767
Corn (lupine)	421	487	200	396
Two-year rotation				
Peanuts (lupine)	106	94	333	176
Corn (native)	592	460	849	634
Three-year rotation				
Peanuts (lupine)	210	228	85	172
Corn (lupine)	831	557	1014	801
Corn (oats)	499	498	460	486

TABLE XXXV

EFFECT ON CROP ROTATIONS ON TOTAL NEMATODE NUMBERS
QUINCY, FLORIDA
July 23, 1954

Cropping Systems	Replications			Av.
	1	2	3	
Continuous:				
Peanuts (native)	228	198	91	149
Peanuts (lupine)	69	103	422	198
Corn (native)	761	556	723	680
Corn (lupine)	1057	590	697	848
Two-year rotation				
Peanuts (lupine)	235	143	153	177
Corn (native)	225	155	150	176
Three-year rotation				
Peanuts (lupine)	331	220	398	316
Corn (lupine)	193	418	445	352
Corn (oats)	656	759	666	694

TABLE XXXVI

EFFECT OF CROP ROTATIONS ON TOTAL REMAINING NUMBERS
QUINCY, FLORIDA
January 14, 1955

Cropping Systems	Replications				Av.
	1	2	3	4	
Continuous:					
Peanuts (native)	116	41	64	65	72
Peanuts (lupine)	30	54	62	60	52
Corn (native)	439	219	204	308	298
Corn (lupine)	342	269	232	420	316
Two-year rotation					
Peanuts (lupine)	180	72	117	85	114
Corn (native)	101	99	118	147	116
Three-year rotation					
Peanuts (lupine)	197	102	52	73	106
Corn (lupine)	114	244	170	227	189
Corn (oats)	280	133	340	106	205

TABLE XXXVII

YIELD OF SWEET CORN FROM VARIOUS FERTILITY LEVELS
SANFORD, FLORIDA
May 20, 1955

Treatments: lbs. per acre 4-5-7 fertilizer	Plot No.	Ears of Corn[1] Wt.(lbs.)	Ears of Corn[1] No.	Plants per plot
0	15	6.5	14	26
0	7	7.0	14	33
0	4	0.0	8	33
0	1	0.0	6	31
1000	12	12.0	20	31
1000	11	18.0	34	37
1000	9	20.0	36	34
1000	3	14.0	25	39
2000	13	25.5	55	35
2000	8	8.0	17	27
2000	5	22.0	36	38
2000	2	8.0	19	35
3000	16	20.0	35	33
3000	14	24.5	41	34
3000	10	18.5	33	33
3000	6	17.5	32	36

[1]Two center rows of each 1/100 acre plots were harvested.

TABLE XXXVIII

NEMATODE COUNTS FROM SWEET CORN AT VARIOUS FERTILITY LEVELS[1] SANFORD, FLORIDA

Treatments: lbs. per acre 4-5-7 fertilizer	Plot No.	Dolichodorus heterocephalus		Trichodorus spp.	
		Mar. 17, 1954	June 2, 1954	Mar. 17, 1954	June 2, 1954
0	15	1	3	0	13
0	7	0	4	1	1
0	4	0	1	0	4
0	1	2	15	0	29
1000	12	1	20	0	16
1000	11	2	13	1	10
1000	9	2	44	1	64
1000	3	0	1	1	14
2000	13	0	6	0	66
2000	8	3	8	0	0
2000	5	1	20	0	36
2000	2	1	11	4	34
3000	16	1	44	0	178
3000	14	1	18	0	59
3000	10	3	17	0	93
3000	6	1	50	0	17

[1]Each value represents the number of nematodes per 150 cc. soil sample.

TABLE XXXIX

CELERY YIELDS FROM VARIOUS FERTILITY LEVELS
SANFORD, FLORIDA
February 1, 1955

Treatments: tons per acre 5-5-8 fertilizer	Plot No.	Celery Harvested (lbs.)[1]		
		Not Blackheart	Blackheart	Total
0	15	21	0	21
0	7	27	0	27
0	4	54	0	54
0	1	84	0	84
1	12	213	0	213
1	11	160	0	160
1	9	205	0	205
1	3	170	0	170
3	13	326	0	326
3	8	358	1	359
3	5	302	0	302
3	0	391	0	391
5	16	128	41	169
5	14	297	31	328
5	10	244	79	323
5	6	312	44	356

[1]Two center rows of each 1/100 acre plot harvested.

TABLE XI

CELERY ROOT WEIGHTS FROM VARIOUS FERTILITY LEVELS
SANFORD, FLORIDA
February 8, 1955

Treatments: tons per acre 5-5-8 fertilizer	Plot No.	No. roots dug[1]	Wt. Roots (oven dry) (gms.)	Av. Root Wt. (oven dry) (gms.)
0	15	32	102	3.19
0	7	36	148	4.12
0	4	51	304	5.96
0	1	39	152	3.90
1	12	39	612	15.70
1	11	39	294	9.19
1	9	25	342	13.54
1	3	45	556	12.37
3	13	30	180	6.00
3	8	51	508	9.94
3	5	34	314	9.24
3	2	41	334	8.14
5	16	38	478	12.50
5	14	33	282	8.58
5	10	41	336	8.18
5	6	44	327	7.43

[1]Roots taken from two center rows of each 1/100 acre plot.

TABLE XII

NEMATODE COUNTS FROM CELERY PLOTS AT VARIOUS FERTILIZER LEVELS[1] SANFORD, FLORIDA

Treatments: tons per acre 5-5-8 fertilizer	Plot No.	Tylenchorhynchus heterocephalus		Trichodorus sp.	
		Dec. 9, 1954	Feb. 8, 1955	Dec. 9, 1954	Feb. 8, 1955
0	15	54	161.0[2]	7	40.5
0	7	30	166.5	96	53.0
0	4	8	24.5	15	42.0
0	1	281	276.5	28	23.5
1	12	193	386.0	97	251.5
1	11	168	341.0	43	185.5
1	9	114	512.5	92	241.0
1	3	36	280.0	47	310.5
3	13	130	210.5	67	207.0
3	8	66	294.5	76	144.0
3	5	188	207.5	119	160.0
3	2	34	158.5	84	214.0
5	16	239	531.0	208	60.5
5	14	184	167.5	180	158.0
5	10	167	381.0	86	228.5
5	6	49	132.5	47	140.5

[1]Each value represents the number of nematodes per 150 cc. soil sample.

[2]Each value on the Feb. 8 sampling date is an average of two laboratory determinations from a common sample.

LITERATURE CITED

1. Anderson, G.J. and I. Yamaguchara. A method of estimating numbers of motile nematodes in large numbers in soil samples. Phytopath. 45: 238-239. 1955.

2. Anonymous. Field crop rotations for root-knot control. Ga. Coastal Plain Exp. Sta. Ann. Rept. (1945). pp. 56-57. 1945.

3. Anonymous. Crop rotations for preventing root-knot damage to tobacco. Ga. Coastal Plain Exp. Sta. Mimeo. Paper Ga. 8. 1949.

4. Baermann, G. Eine einfache Methode zur Auffindung von Ankylostomum (Nematoden) Larven in Erdproben. Genesk. Tijdsch. v. Nederl. Ind. 57: 131-137. 1917.

5. Bastin, H. G. Monograph on the Anguillulidae, or free nematoids, marine, land, and freshwater; with descriptions of 100 new species. Trans. Linn. Soc. 25: 73-184. 1865.

6. Baylis, H. A. and G. Daubney. A synopsis of the families and genera of Nematoda. (British Museum, London). 1926.

7. Bunyer, G. M. Common names of some important plant pathogenic nemas. Pl. Dis. Reptr. 38: 535-541. 1954.

8. Chapman, G. A. Meadow nematodes associated with failure of spring-sown alfalfa. Phytopath. 44: 542-545. 1954.

9. Chitwood, G. G. Ring nematodes (Criconematinae). A possible factor in decline and replanting problems of peach orchards. Helminth. Soc. Wash. (Proc.) 16: 6-7. 1949.

10. Chitwood, G. G. and G. A. Oteifa. Nematodes parasitic on plants. Ann. Rev. Microbiol. 6: 151-184. 1952.

11. Christie, J. R. Some new nematode species of critical importance to Florida growers. Soil Sci. Soc. Fla. (Proc.) 12: 30-39. 1952.

12. Christie, J. G., A. G. Brooks, and V. G. Perry. The sting nematode, Belonolaimus gracilis, a parasite of major importance on strawberries, celery, and sweet corn in Florida. Phytopath. 42: 173-176. 1952.

13. Christie, J. G., J. M. Good, and G. G. Nutter. Nematodes associated with injury to turf. Soil Sci. Soc. Fla. (Proc.) 14: (in press). 1954

14. Christie, J. G. and V. G. Perry. A root disease of plants caused by a nematode of the genus Trichodorus. Sci. 113: 491-493. 1951.

15. Christie, J. R. and V. H. Perry. Removing nematodes from soil. Helminth. Soc. Wash. (Proc.) 18: 106-108. 1951.

16. Clayton, E. E. Root-knot of peach affected by cover crops. Mimeo. paper of seminar on "Cover crops in N. C." (N. C. State College of Agr.) pp. 162-163. 1951.

17. Clayton, E. E., J. G. Gaines, H. J. Smith, H. J. Shaw, and F. W. Graham. Control of flue-cured tobacco root diseases by crop rotation. N. C. A. Farmer's Bul. No. 1958: 1-12. 1944.

18. Cobb, N. A. New nematode genera found inhabiting fresh water and non-brackish soils. J. Wash. Acad. Sci. 3: 342-344. 1913.

19. Cobb, N. A. North American free-living fresh-water nematodes. Trans. Am. Micro. Soc. 33: 69-134. 1914.

20. Cobb, N. A. A new parasitic nema found infesting cotton and potatoes. J. Agr. Res. 11: 27-33. 1917.

21. Cobb, N. A. Estimating the nema population of soil. U. S. D. A. Agr. Tech. Cir. No. 1: 1-47. 1918.

22. Cobb, N. A. A new nema, Tylenchus musicola, said to cause a serious opposition of Blugoe bananas in Grenada, British West Indies. West Indian Bul. 17: 179-182. 1919.

23. Cobb, N. A. An emendation of Hoplolaimus Daday 1905, nec. auctorum. J. Wash. Acad. Sci. 13: 211-214. 1923.

24. Curt, W. W., J. H. Ackert, H. L. Augustine, and F. H. Payne. Investigations on the control of hookworm disease. II. The description of an apparatus for isolating infective hookworm larvae from soil. Am. J. Hyg. 2: 1-16. 1922.

25. Grossman, L. and J. H. Christie. List of plants attacked by miscellaneous plant-infesting nematodes. Fl. Dis. Reptr. 21: 144-167. 1937.

26. Daday, E. Untersuchen uber die Susswasser-Mikrofauna Paraguays. Zoologica 18: 1-349. 1905.

27. Dieter, G. H. Techniques for collecting and isolating plant parasitic nematodes. Down to Earth 10: 8-11. 1954.

28. Fodor, V. A. and J. Feldmesser. The Buchner funnel as an aid in collecting and concentrating nematode populations. Fl. Dis. Reptr. 38: 805-806. 1954.

29. Filipjev, I. T. The classification of free living nematodes and relation to parasitic nematodes. Smithsonian Misc. Col. 89: 1-63. 1934.

30. Filipjev, I. T. and J. H. Schuurmans Stekhoven. A manual of agricultural helminthology. (E. J. Brill, Leiden). 1941.

31. Gadd, T. H. and T. A. Lees. Observations on the life history of Anguillulina pratensis. Ann. Appl. Biol. 28: 39-51. 1941.

32. Garrison, T. T. Nematode control in flue-cured tobacco. T. H. Agr. Ext. Cir. No. 374: 1-15. 1953.

33. Goffart, T. Der wiesennematode, Pratylenchus pratensis (de Man 1880), ein wenig bekannter getreideschädling. Ztschr. f. Pflanzenkrank. 52: 268-269. 1942.

34. Good, J. T., J. T. Christie, and T. T. Hutter. Nematodes are causing extensive damage to Florida turf. Fla. Turf Assoc. Bul. 1: 7-8. 1954.

35. Good, J. M. and W. T. Blue. Relationships between plant parasitic nematodes, pathogenic fungi, and Ladino clover yields in experimental pot studies. Soil Sci. Soc. Fla. (Proc.) 14: (in press). 1954.

36. Goodey, T. A new dorylaimid nematode Xiphinema radicicola n. sp. J. Helminth. 14: 69-72. 1936.

37. Goodey, T. Soil and freshwater nematodes. (John Wiley & Sons, Inc., N. Y.). 1951.

38. Goodey, T. Laboratory methods for work with plant and soil nematodes. Ministry of Agr. and Fish. Tech. Bul. No. 2: 1-25. 1951.

39. Graham, T. T. The meadow nematode on tobacco in South Carolina. Fl. Ins. Soytr. 26: 410. 1942.

40. Graham, T. T. Nematode root-rot of tobacco and other plants. S. C. Exp. Sta. Bul. 320: 1-25. 1951.

41. Graham, T. T. Nematodes as ectoparasites on tobacco, cotton, and other plants. (Abs.) Phytopath. 42: 9. 1952.

42. Graham, T. W. and G. L. Malderman. The sting nematode Belonolaimus gracilis Steiner: A parasite on cotton and other plants in South Carolina. Phytopath. 43: 434-439. 1953.

43. Hastings, R. J. The biology of the meadow nematode Pratylenchus pratensis (de Man) Filipjev 1936. Canad. J. Res. 17: 39-44. 1939.

44. Hastings, R. J. and J. H. Rouhan. A study of the pathogenicity of the meadow nematode and associated fungus Cylindrocarpon radicicola Wr. Canad. J. Res., Sec. D. 16: 225-229. 1938.

45. Halderman, G. L. The present known distribution of the sting nematode, Belonolaimus gracilis, in the Coastal Plain of the Southeastern United States. Fl. Dis. Reptr. 39: 5-8. 1955.

46. Halderman, G. L. and T. W. Graham. The effect of different plant species on the population trends of the sting nematode. Fl. Dis. Reptr. 37: 497-500. 1953.

47. Jenkins, W. A. A root rot disease complex of tobacco in Virginia. I. Brown root rot. Phytopath. 38: 528-541. 1948.

48. Kincaid, R. R. Soil factors affecting incidence of root-knot. Soil Sci. 61: 101-109. 1946.

49. Kincaid, R. R. Management of cigar-wrapper tobacco plant beds in Florida. U. of Fla. Agr. Exp. Sta. Press. Bul. 637: 1-4. 1947.

50. Kincaid, R. R. and J. Reeves. Cultural practices for root-knot nematode control between annual crops of cigar-wrapper tobacco. U. of Fla. Agr. Exp. Sta. Bul. 382: 1-16. 1943.

51. Linford, M. B. Parasitism of the root-knot nematode in leaves and stems. Phytopath. 31: 634-648. 1941.

52. Lordello, L. G. E. Xiphinema brasiliense, nova especie de nematoide do Brasil, parasitica de Solanum tuberosum L. Bragantia 11: 87-90. 1951.

53. Lordello, L. G. E. Nematodes attacking soybean in Brazil. Fl. Dis. Reptr. 39: 310-311. 1955.

54. Lordello, L. G. E. Xiphinema krugi n. sp. (Nematoda, Dorylaimidae) from Brazil with a key to the species of Xiphinema. Helminth. Soc. Wash. (Proc.) 22: 16-21. 1955.

55. Machmer, J. H. Root-knot of peanut. I. Distribution. Fl. Dis. Reptr. 35: 364-366. 1951.

56. Machmer, J. H. Criconemoides sp., a ring nematode associated with peanut "yellows". Fl. Dis. Reptr. 37: 156. 1953.

57. Machmer, J. H. The nematode complex in Southern Georgia. Fl. Dis. Reptr. Suppl. 207: 102-107. 1954.

58. Man, J. D., de. Die einheimischen, frei in der reinen Erde und in süssen Wasser lebenden Nematoden. Tijdschr. Nederl. Dierk. Ver. 5: 1-104. 1880.

59. McBeth, C. W. and A. L. Taylor. Immune and resistant cover crops valuable in root-knot infested peach orchards. Am. Soc. Hort. Sci. (Proc.) 45: 158-166. 1944.

60. Micoletzky, H. Neue freilebende nematoden aus Suez. Akad. der Wiss. Wien, Math. Nat. Kl. 131: 77-103. 1922.

61. Mountain, W. B. Studies of nematodes in relation to brown rot of tobacco in Ontario. Canad. J. Bot. 32: 737-759. 1954.

62. Mountain, W. B. and L. W. Koch. Nematode diseases of tobacco in Ontario. Canad. Dept. Agr., Bot., and Pl. Path. Div., Sci. ser. Contribut. No. 1402: 1-4. 1955.

63. Neal, J. C. The root-knot disease of peach, orange, and other plants in Florida, due to the work of Anguillula. U. S. Div. Bot. Bul. No. 20: 1-31. 1889.

64. Oostenbrink, M. On the significance of migratory root colonizers in agriculture and horticulture. Verslag. en mededl. Plantenziektenkund. Dienst Wageningen 104: 196-233. 1954.

65. Oostenbrink, M. Een doeltreffe methode voor het toetsen van altijdoestrijdingsmiddelen in grond met Hoplolaimus uniformis als proefdier. Overdruk uit mededelingen van de landbouwhogescholen de opzoekingsstations van de staat te Gent. Deel. 19: 377-408. 1954.

66. Oteifa, B. A. Effects of potassium nutrition and amount of inoculum on rate of reproduction of Meloidogyne incognita. J. Wash. Acad. Sci. 41: 393-395. 1951.

67. Oteifa, B. A. Potassium nutrition of the host in relation to infection by root-knot nematode Meloidogyne incognita. Helminth. Soc. Wash. (Proc.) 19: 99-104. 1952.

68. Oteifa, B. A. Development of the root-knot nematode Meloidogyne incognita, as affected by potassium nutrition of the host. Phytopath. 43: 171-174. 1953.

69. Owens, J. V. The pathological effects of Belonolaimus gracilis on peanuts in Virginia. (Abs.) Phytopath. 41: 29. 1951.

70. Parris, B. F. and B. A. Jehle. Root-knot nematode on lima beans in Maryland. Pl. Dis. Reptr. 27: 235. 1943.

71. Perry, V. G. The awl nematode, Dolichodorus heterocephalus, a devastating plant parasite. Helminth. Soc. Wash. (Proc.) 20: 21-27. 1953.

72. Raski, D. J. On the morphology of Criconemoides Taylor, 1936, with descriptions of six new species. Helminth. Soc. Wash. (Proc.) 19: 85-99. 1952.

73. Raski, D. J. Methods of detecting and investigating plant parasitic nematodes. Phytopath. 43: 259-263. 1953.

74. Sasser, J. N. Populations dynamics of nematode parasites of tobacco in certain crop rotations. (Thesis. N. C. State College of Agr.) 1950.

75. Sasser, J. N. Identification of host-parasite relationships of certain root-knot nematodes (Heloidogyne spp.). U. of Md. Agr. Exp. Sta. Bul. A-77: 1-31. 1954.

76. Schindler, A. F. Root galling associated with dagger nematode, Xiphinema diversicaudatum (Micol., 1927) Thorne, 1939. (Abs.) Phytopath. 44: 389. 1954.

77. Steinbergt, J. W. De Betenkis van de Toestand voor het Optreden van Aantasting door het stengelaaltje, Ditylenchus dipsaci (Kuhn) Filipjev. Tijdschr. Plziekt. 56: 291-349. 1950.

78. Shor, S. A. and M. W. Allen. Revision of the genus Pratylenchus (Nematoda: Tylenchidae). Univ. of Calif. Pub. in Zool. 57: 441-470. 1953.

79. Steiner, G. Tylenchus pratensis and various other nemas attacking plants. J. Agr. Res. 35: 901-911. 1927.

80. Steiner, G. Nemas causing plant galls controlled best through crop rotation. U. S. D. A. Yearbook pp. 391-394. 1930.

81. Steiner, G. Diseases caused by meadow nematodes, Tylenchus pratensis de Man on strawberry, tobacco, and tomato. Fl. Ns. Reptr. 15: 106-107. 1931.

82. Steiner, G. Plant parasitic nematodes the grower should know. Soil Sci. Soc. Fla. (Proc.) 4 (B): 72-117. 1942.

83. Steiner, G. Meadow nematodes as the cause of root destruction. Phytopath. 35: 935-937. 1945.

84. Taylor, A. S. Utilization of the Baermann method as a means of assay of root infection by meadow nematodes, Pratylenchus spp. (Abs.) Phytopath. 39: 25. 1949.

85. Taylor, A. C. A consideration of mineral nutrition of boxwood in relation to infection by meadow nematodes, Pratylenchus spp. J. Wash. Acad. Sci. 40: 157-160. 1950.

86. Taylor, A. C., W. F. Loomsberry, and W. O. Hanley. Pathogenicity of some plant-parasitic nematodes from Florida soils. I. The effect of Bolichodorus heterocephalus Cobb on celery. Phytopath. 42: 131-132. 1952.

87. Taylor, A. L. The genera and species of the Criconematinae, a sub-family of the Anguillulinidae (Nematoda). Trans. Am. Micro. Soc. 60: 391-421. 1936.

88. Taylor, A. L. and W. Q. Loegering. Nematodes associated with root lesions in Abaca. Turrialba. 3: 1-2, 8-13. 1953.

89. Thorne, G. On the classification of the Tylenchida, new order (Nematoda, Phasmidia). Helminth. Soc. Wash. (Proc.) 16: 37-73. 1949.

90. Thorne, G. and M. W. Allen. Pratylenchus hamatus n. sp. and Xiphinema index n. sp., two nematodes associated with fig roots, with a note on Pratylenchus vulnus Cobb. Helminth. Soc. Wash. (Proc.) 17: 27-35. 1950.

91. Thompson, L. U. and W. K. Robertson. Effect of rotations, fertilizers, lime, and green manure crops on crop yields and on soil fertility. U. of Fla. Agr. Exp. Sta. Bul. 522: 1-32. 1953.

92. Todd, F. A. The effect of cover crops on the incidence of root-knot and the yield and value of tobacco. Mimeo. paper of seminar on "Cover crops in N. C." (N. C. State College of Agr.). pp. 151-157. 1951.

93. Tyler, J. The root-knot nematode. Calif. Agr. Exp. Sta. Cir. 330: 1-30. 1944.

94. Watson, J. W. Dunch velvet beans to control root-knot. U. of Fla. Agr. Exp. Sta. Bul. 163: 1-39. 1922.

95. Wilferth, H. and G. Wimmer. Untersuchungen über die Wirkung der Nematoden auf Ertrag und Zusammensetzung der Zuckerrüben. Stschr. d. Ver. d. Deutsch. Zuckerindus. 53: 1-41. 1903.

96. Wilson, C. Root-knot nematodes on peanuts in Alabama. Fl. Dis. Reptr. 32: 443. 1948.

97. Young, T. W. An incubation method for collecting migratory endoparasitic nematodes. Fl. Dis. Reptr. 38: 794-795. 1954.

BIOGRAPHICAL ITEMS

Joseph Martin Good, III, was born in Atlanta, Georgia, on November 18, 1927. His primary and secondary education was received in a number of schools in Tennessee, Georgia, and Florida. He was graduated from the Gainesville High School at Gainesville, Florida, in 1945. He entered Emory University in 1945 and received his B. A. degree in 1950. For a brief period, September 10, 1946, to February 10, 1948, he served in the United States Army. While in the Army he was graduated from the School of Military Psychiatric Social Work at Brooke Army Medical Center, Fort Sam Houston, Texas. As a senior at Emory University he was awarded a teaching assistantship in the Department of Biology, and later as a graduate student in the same university was awarded a graduate fellowship in the Department of Biology. He received his M. S. from Emory University in 1953. In 1950 he entered the University of Florida to work toward the degree of Doctor of Philosophy in the Soils Department, College of Agriculture, where his major subjects were in soil microbiology and minor subjects in biology. While at the University of Florida, he was employed by the Soils Department as a one-third time laboratory assistant from 1950 to 1953, and as a full-time laboratory assistant from 1953 through the writing of this manuscript.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of the committee. It was submitted to the Dean of the College of Agriculture and to the Graduate Council and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 13, 1955

C. V. Noble
Dean, College of Agriculture Made

Dean, Graduate School

SUPERVISORY COMMITTEE:

Chairman

E Ruffin Jones

J W Thurston

L A Hatrick

F B. Smith

H O Banks